Sewage Works Journal

Published by

Federation of Sewage Works Associations

Lancaster, Pa.

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Sewage Works

FINANCING SEWAGE WORKS *

By Francis S. Friel

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The financing of the construction of municipal sewage works under present conditions of high costs is of concern to many engineers and municipal officials. Prior to the war, construction costs were low as compared to today's high prices and, in addition, it was possible for a great number of municipalities to secure aid from the Federal Government for constructing these facilities.

Present construction costs (1946) are 111.6 per cent above the 1933 level, and 49 per cent above the 1940 level based on *Engineering News-Record* Index. On the other hand, the interest rates on municipal bonds are lower today than ever before. With this lower interest rate, the annual amortization or debt service costs do not reflect an overall increase in the cost of a project, as might be expected when consideration is given only to construction cost increases.

Within the last 10 years new methods for financing sewage works have been enacted into the laws of many states. These new laws were adopted in some instances in order to permit municipalities to take advantage of Federal aid. Definite progress has been made in making available new methods of financing. Because of the new laws and methods, a state government today can make more forceful demands upon a municipality for sewage treatment, since it is now supported by acts which enable it to compel a municipality to "show action."

The problem of financing the cost of a complete sewer system and sewage treatment plant differs from that of financing the cost of sewage treatment facilities alone. A great many municipalities have sewer systems but only partial sewage treatment facilities; others provide no treatment at all.

The construction of sewage works is generally carried out by a municipality, financing and construction being managed by its legislative body and administrative officers. In some instances, however, metropolitan districts, sanitation commissions, and municipal sewer authorities have been created under legislative acts for performing the administrative functions connected with the collection and treatment of sewage. These special organizations have been established in many states and have been successful. Some of these districts and commissions function as state agencies, as the Metropolitan District Commission of Massachusetts. In this case its functions are controlled by the state. Others, such as the Milwaukee Sewerage Commission, are under the control of the city, and the administrative officers are appointed by the municipality. Another type of special organization is the independent corporation which in Pennsylvania is called the "Municipal Authority." When established, it operates independently, issuing bonds for construction purposes, and after the system is placed in service it collects revenues to pay

* Presented at Nineteenth Annual Meeting, Federation of Sewage Works Associations; Toronto, Ont., Can., October 7–9, 1946.

interest, sinking fund, operation and other costs. The Sanitary District of Chicago and the Minneapolis-St. Paul Sanitary District fall within this classification. In Pennsylvania a municipal authority might issue bonds and control the design and construction of a project, and then lease the completed facilities to the municipality for operation.

The nation is becoming stream pollution conscious, and a growing need for additional and more complete treatment of the sewage from municipalities is evident. In January, 1945, the Pennsylvania Sanitary Water Board directed 183 municipalities to prepare plans for sewage treatment. Supplemental orders were later issued to 92 similar governmental units. Other states today are likewise engaged in active programs for stream pollution abatement, and a large number of municipalities are faced with the problem of constructing sewage collection and treatment works.

The construction of these facilities involves the problem as to how this new financial burden may be added to the present heavy demands which are made upon the taxpayers. Should new bonds be issued, should the project be constructed out of current revenues, should sewer rentals be charged to pay the debt service charges and operating costs, or should the carrying charges be obtained through increased taxation? In many instances a municipality does not have sufficient borrowing capacity to finance sewage construction, and it must depend upon other methods of financing, such as the issuance of revenue bonds.

Common Methods of Financing

The common methods by which a municipality may raise funds for the construction of sewage facilities are:

1. General obligation bonds.
2. Special assessments or special assessment bonds.
3. Current revenue from existing sources or from reserves.
4. Revenue bonds or revenue certificates.
5. Creation of a special organization or independent corporation, such as a municipal authority, a metropolitan district, a sanitation commission or a sanitary district.
6. Temporary loans.
7. By a combination of two or more of the above methods.
8. Through a privately owned sewer company.

General Obligation Bonds

The first and most commonly used method is the issuance by a municipality of general obligation bonds, the proceeds of which are to pay all costs for constructing a complete sewer system, including the branch sewers as well as outfall sewers, pumping stations, force mains and sewage treatment plant. The ability of a municipality to issue general obligation bonds is dependent upon its borrowing capacity and such bonds can be issued only within the limits set by the legislation which governs this function. In the state of Pennsylvania a municipality may incur a debt of 2 per cent of its assessed valuation of property for taxing purposes without obtaining the consent of the electors, and up to 7 per cent with the consent of the electors.

General obligation bonds are secured by the general taxing powers of a municipality and in some states are issued in serial form maturing annually, and in other instances they are issued to mature at the termination of the life of the bonds. The procedure may vary depending upon the laws of the state.

This type of bond is attractive to investors because it is backed by taxing power and, therefore, usually bears a lower interest rate than a revenue bond. On the other hand, it uses a

large portion of borrowing capacity for one special purpose.

Special Assessments or Special Assessment Bonds

The next method of financing sewage projects is by assessing the cost against the abutting property owners. When bonds are issued for this purpose they are often known as "baby bonds," and the abutting owners are assessed for the retirement of the bond. In Pennsylvania, only the cost of the sewers may be assessed against property owners abutting the lines. This method of financing is seldom if ever used exclusively, since part of every sewage system is non-assessable, and it is usually necessary to supplement the assessments with the proceeds from some other type of bond, such as general obligations.

There are two commonly used methods of assessing the cost of part of a sewer system; one is by benefits and the other is by the "front-foot rule." Where a municipality cannot afford to issue general obligation bonds for an entire sewage project, it often can issue sufficient bonds to provide funds for the non-assessable costs, such as the sewage treatment plant, the outfall sewers, the pumping stations and the force mains, permitting the cost of the collection system to be borne by the property owners abutting on and benefiting by the sewers.

In some states it is customary to pay the contractor in assessment bonds, which before the war bore interest rates of 5 to 6 per cent. This type of bond is redeemed when the property owner pays his assessment. It is also the practice in many localities to permit property owners to pay the assessment over an extended period of 5 or 6 years, by charging interest on the unpaid balance. In some states the sewer assessment bonds are secured solely by the assessment and are not supported by the general taxing power of a municipality. This was once the case in Pennsylvania, but the Legislature has since provided that sewer assessment bonds are to be secured by the general taxing power of a municipality. In Pennsylvania, it is now the custom to issue short-term serial general obligation bonds (say 5 years) for constructing branch sewer lines; the assessments are collected from the abutting property owners and the short-term obligations are then retired.

Special assessment financing has been used extensively for sewer construction and appears to be more practical for this purpose than for financing the cost of sewage treatment facilities, although in many states the latter procedure is permitted and has been successful.

Current Revenue from Existing Sources or Reserves

It is not customary for a municipality to use current revenues or reserves for major construction operations. This method might be used for minor extensions, provided the construction cost is not great.

In some states reserves were increased during the war period due to a curtailment of normal repair and maintenance operations. Limited funds are therefore available for use as capital costs. In many states, however, the budget of municipalities is governed by state regulations which do not permit the accumulation of a reserve.

Revenue Bonds or Revenue Certificates

"Non-debt" revenue bonds or revenue certificates are secured solely by revenue derived from sewer rentals or from sewer service charges. The debt created is usually not included in the constitutional or statutory limits provided by law. The annual sewer rentals or sewer service charges which may be imposed under this method should be sufficient to meet all expenses including:

(a) The costs of operation, maintenance, repair, alteration, inspection, depreciation and other expenses.

(b) Such annual amount as may be necessary to provide for the amortization of the revenue bonds issued by the municipality to finance construction of the facilities, together with interest thereon, in order that the improvements may become self-liquidating.

(c) Sufficient allowance for the establishment of a margin of safety of not less than 10 per cent.

In some states the annual sewer rental or sewer service charge which is imposed by a municipality may be made a lien on the property, and may be collected in the manner provided by law for the filing and collection of municipal liens. This method of financing is used effectively where a municipality does not have sufficient borrowing capacity to finance the project with general obligation bonds. The revenue bond usually bears a higher interest rate than general obligation bonds since it is not supported by the taxing power of a municipality.

Because of a decision of the Supreme Court of Pennsylvania in the case of Lighton *et al.* vs. Abington Township, 336 PA 345–368 (1939), the leading bond attorneys in Pennsylvania have been unwilling to give their approval to the non-debt revenue sewer bond. While the Court in that case did not specifically hold that the Act under which such bonds could be issued was unconstitutional, it did hold that the method by which the security of the bonds was to be enforced in the Abington case was in violation of the Constitution. The Abington indenture provided that, in case of a default in the payment of the carrying charges on the bonds to the trustee, and said trustee could take actual possession of the sewer system and operate it so that interest and sinking fund payments and operating costs could be met. The Court held that the delegation of this power to the trustee by the municipality was unconstitutional under a particular provision of the Pennsylvania Constitution. The Court further indicated that it was not in favor of sustaining legislation which permitted municipalities to circumvent constitutional limitations on debt.

The use of non-debt revenue sewer bonds in Pennsylvania is therefore not generally practiced. In the case of first-class cities (Philadelphia only), however, there is a provision in the Constitution (Section 15, Article 9) which permits a debt that is self-supported by rentals or revenue to be free and not charged against the debt limit of the city.

Special Districts, Commissions and Authorities

A municipal authority, metropolitan district, sanitation commission or sanitary district is a special body which is established to perform the function of providing sewage service. This type of organization may be created by one municipality or jointly by several municipalities or other political subdivisions. For all practical purposes it is substantially the same as a corporation, and the laws in many states authorize the formation by a municipality of a corporation which is separate and distinct from the municipality itself.

Among the powers granted to this type of organization is the power to borrow money and to issue bonds and, for that purpose, to enter into a deed of trust or indenture in which the revenues received are pledged as security for the bonds. Thus, if a municipality is unable to finance the construction of sewage facilities by either general obligation or assessment bonds, it may organize this type of independent corporation which has the power to construct the facilities, to charge the property owners for their use, and to finance the construction by the issuance of bonds secured by sewer rentals or sewer service charges.

With this type of organization, the revenues from sewer rentals must begin within a reasonably short period of time after the bonds are issued so that debt service charges can be met. On a newly constructed sewer system it is prudent to delay the first retirement of the serial bonds for approximately five years after the start of construction of the project. This will allow time for sewer connections to be made (Figure 1). Where a sewer system is already in service and where only sewage treatment facilities are to be constructed, the sewer rentals may be charged immediately.

In 1935 the Legislature of Pennsylvania enacted the Municipal Authorities Act which authorizes the formation of an independent organization to perform the functions above described. Since then 100 authorities have been established, 9 of which operate sewer systems. The municipal authority has been found to be most effective, especially for joint projects involving large numbers of political subdivisions.

Special independent organizations have been created in many states by enabling legislation to perform the function of rendering sewage service. Reference has already been made to the Metropolitan District Commission of Massachusetts, to the Milwaukee Sewerage Commission, to the Sanitary District of Chicago and to the Minneapolis-St. Paul Sanitary District.

The Sanitary District of Chicago was established in 1889 and the North Shore Sanitary District in 1911, both under special state laws. In 1917 the Illinois Legislature enacted a general sanitary district law and, by 1946, there were 28 districts operating under this Act.

The Illinois law provides that the residents of the area to be served must petition for an election to determine the question of the establishment of a district. A district so established by a majority of the electors has the power to levy and collect taxes and to issue bonds not to exceed 5 per cent of the valuation of taxable property. A district may also apportion and collect an additional charge for the treatment of industrial wastes, and may levy special assessments on properties which benefit by the construction of collecting sewers. Greeley, in his paper entitled "Organizing and Financing Sewage Treatment Projects" (ASCE *Proceedings*, December, 1942), stated:

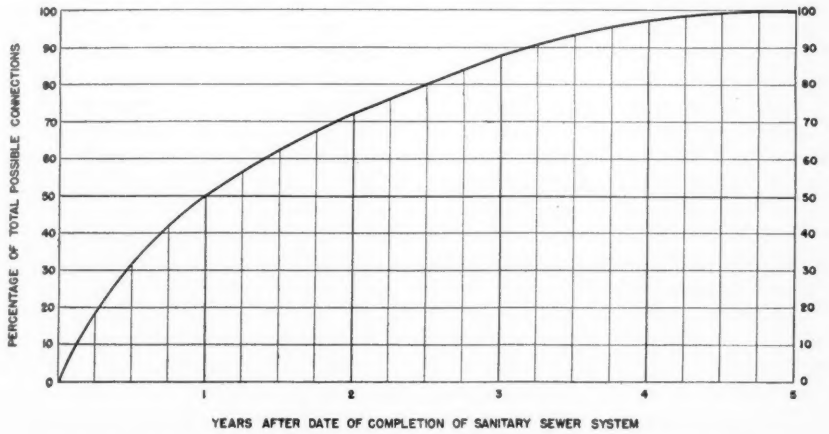

FIGURE 1.—Curve showing rate of connections to newly completed sanitary sewer system.

"The experience in Illinois in the administration of Sanitary Districts under the 1917 Act has been so good that this method of procedure could well be extended to other parts of the United States."

The Regional Hampton Road Sanitation Commission, Hampton Road, Va., was established by an election and came into existence by the appointment of five commissioners by the Governor. This commission may construct and operate sewage treatment projects.

The East Bay Municipal Utilities District in California may purchase or construct revenue-producing utilities after approval by vote of the people. Rawn, in his paper "Sewer Rentals" (*Public Works Engineer's Year Book*, 1941), states:

"The recently enacted Sewer Revenue Bond Act in the State of California provides for the construction of sewerage systems to be financed by revenue bonds which in turn are repayable from sewer rental charges. It is complete, comprehensive and is based upon the best practices throughout the United States."

The Passaic Valley Sewerage Commission of New Jersey may formulate projects but cannot construct them until a prescribed number of municipalities within the district have approved the plan and have further obligated themselves to furnish the construction funds.

The Washington Suburban Sanitary District, embracing Prince George's and Montgomery Counties, Maryland, is empowered to construct and maintain sewage disposal projects. It may borrow money, levy a tax or make special assessments and service charges.

The Buffalo, N. Y., Sewer Authority is authorized to issue revenue bonds for construction purposes.

The Michigan law allows the incorporation of any two or more municipalities into metropolitan districts. Communities of Wayne County, Mich., have formed regional organizations, which have contracted with the city of Detroit for treatment of the sewage.

In Wisconsin, some 40 sanitary districts have been organized in unincorporated township areas. Most of these districts discharge sewage to large neighboring communities, while a few have their own treatment facilities. The district is started by a petition to the Town Board of 60 per cent of the property owners in the area. A Town Board establishes boundaries and appoints three commissioners who may issue general obligation bonds up to 5 per cent of assessed valuation. They may also issue revenue bonds.

The Baltimore County Metropolitan District (Maryland) may borrow 7 per cent of the assessed valuation of the area serviced, for water and sewage facilities, and may issue general obligation bonds not exceeding 50 years in term. It is the practice to issue 40-year bonds. The cost of constructing sewer lines is assessed against abutting property owners on the basis of an annual payment of 15 cents per foot of pipe per year for 40 years. The cost of the sewer construction, in this case, was expected to be amortized in a 40-year period. (The 15 cents per foot was sufficient prior to the war, but today this unit price is inadequate to meet the interest payments and to amortize the bonds in 40 years.) In addition to this annual charge covering construction costs, the Baltimore County Metropolitan District also levies a charge of $6.32 per year for the operation and maintenance of the sewer lines and of the sewage treatment facilities. In the case of a deficiency, the district is empowered to levy an *ad valorum* tax to make up the deficiency. Property owners pay the costs of constructing the house connection from the sewer line in the street at the rate of $4 per lineal foot.

In Indiana, municipalities may issue revenue bonds secured only by revenue from service charges. This provision is set forth in the Revenue Bond Act of 1932 (amended 1933). Sewer rentals and sewer service charges, in this

case, must be sufficient to carry all expenses, including sinking funds, retirement of bonds and with a margin of safety added. The debt service charge has priority on revenues and the remainder of the annual revenue is used for operation, depreciation and maintenance. After these charges are paid, if any funds remain they are transferred to the sinking fund or to a fund for extensions, betterments and additions. The courts have ruled that these bonds do not constitute a debt of the municipality.

In Florida the 1935 Legislature passed an act authorizing any community to issue mortgage revenue certificates or debentures without regard to limitations of municipal indebtedness for the construction and operation of "public works." These certificates do not constitute a debt against the municipality, but they form a lien upon the property and the revenues of the utility. Gillespie, in his paper entitled "Financing Sewage Construction in Florida" (THIS JOURNAL, September, 1944), stated:

"Florida communities which have proceeded under this plan have operated successfully, including Tallahassee and Clearwater. This provides a workable means for many Florida communities to finance sorely needed sanitary improvements."

The Florida courts recently upheld the Miami sewer revenue bond plan, and this decision is considered to be of primary importance. The decision sustains the financing on a revenue bond basis without an election. It sustains the basis of the sewer service charges, the shutting off of water for the non-payment of such charges and the forcing of property owners to connect their premises with the sewer system. The Miami sewer revenue bonds, for all practical purposes, will afford as good security as its water revenue bonds.

It is understood that the first municipal revenue bonds issued in this country were based on water revenue at Spokane, Wash., and that the sinking fund and the interest on the bonds was payable exclusively from the income of the Spokane water works. It was established that these bonds did not constitute a general obligation of the municipality, and that a municipality could issue this type of bond or certificate which would not be classified as a direct obligation. It appears that the Spokane case established the legality of a bond which is based solely upon service revenues.

Temporary Loans

If the construction cost is not excessive, temporary short-term loans may be used to finance sewage projects. This procedure eliminates the necessity of long-term annual plan payments. If the capital expenditure can be repaid out of the current revenues in less than five years, this method of procedure might be advantageous.

Combinations of Two or More Methods

Good financing indicates that money should be borrowed and bonds issued only for funds which cannot be raised in other ways. Therefore, if any cash on hand or excess revenue is available to help defray the cost of construction, the amount of a bond issue may be reduced with a corresponding saving in the annual debt service.

Reference has already been made to the possibility of combining special assessments with the proceeds of general obligation bonds. This is a practical procedure which has been employed on numerous occasions by the author. If the sewers are assessed against the abutting property owners, and the cost of the sewage treatment facilities, pumping stations, force mains and outfall sewers are financed through general obligation bonds, the result is that the property owner would make a down payment for branch sewer construction which before the

war without Federal aid in the Eastern Pennsylvania region amounted to approximately $3 per front foot. The sewer rental required to pay the interest and sinking fund on the bonds and to operate the facilities ranged between $10 and $15 annually. If the entire cost of construction, including the branch sewers, was financed by revenue bonds, the annual rental would have ranged between $20 and $25 per year, based on pre-war construction costs. Today the issuance of revenue bonds to finance completely the construction of sewage collection and treatment facilities would result in an annual sewer rental per property ranging from $30 to $35.

The combination as practiced by the Baltimore County Metropolitan District was a well-conceived plan and appears to be a suitable method of employing a combination of financial principles.

Privately Owned Sewer Companies

Pennsylvania has more privately owned sewer companies rendering sewage service than any other state. Fourteen of these privately owned corporations are in existence; most of them were established many years ago.

A private corporation is required to pay State and Federal income and other taxes and also is entitled to receive a larger return on its invested capital than the interest rate which is now paid on municipal bonds. It therefore appears more economical for a municipality to construct sewage works by any of the seven methods hereinbefore described than to grant a franchise to a privately owned corporation. The author has been associated with the construction of additional facilities and with the operation of several privately owned sewer companies, and it is believed that a private company can operate as economically, if not more so, than a municipality.

One distinct disadvantage to the private sewer company is its inability to enforce sewer connections. A municipality has the power to enact laws compelling connections to be made to a sewer system, whereas a private utility must depend upon voluntary connections by the property owners. The fewer the connections to the sewer system, the higher will be the annual rental per unit of property served. The author has knowledge of one municipality served by a private sewer company where not more than 60 per cent of the houses are connected to the sewer lines, in spite of the fact that the town is entirely sewered.

Revenue from Other Municipal Utilities

One unusual method of financing the construction of sewage works would be to secure bonds covering part of the capital cost by revenue from other utilities owned by the municipality. This procedure makes it possible to reduce the annual sewer rental charge.

The author has recently developed a plan to finance a municipal sewer system by this method. The total cost of the project is $310,000. The municipality owns its water works and has sufficient annual surplus from water works operation to support a bond issue of $125,000. The water works system will be conveyed to an authority and in turn leased back to the municipality for operation. The $125,000 bond issue supported by water works revenue will be added to a second bond issue of $185,000 supported by sewer rental revenue, thus making $310,000 available for the construction of the sewage facilities. This procedure makes possible the establishment of a low annual sewer rental. It does not require an increase in water rental, but on the other hand it does use up the annual operating surplus from the water works system.

A plan which accomplishes a result similar to that described above, with the combination of water and sewage under one operating head within the

municipal government and with the use of limited sums of water works operation surplus for financing sewage projects, was enacted in 1943 by the Ohio Legislature. This Act provides for the accumulation of a reserve each year of 5 per cent of the gross revenue before any diversion can be made to the sewage works fund. It further provides that 10 per cent of the gross revenue of the water works operation may be taken from surplus to provide only for the payment of the cost of operation, maintenance and repair of the sewage system, sewage pumping, sewage treatment and disposal works, or it may be used for the enlargement or replacement of these facilities.

The Yakima, Washington, sewage treatment plant is operated by the Water Department, which adds 20 per cent to the water rates to cover sewage treatment plant operation costs.

Plan of Procedure from an Engineering, Financial and Legal Viewpoint

The engineers who design sewage facilities have the responsibility of producing a system which will provide the required service at a minimum cost of construction, operation and maintenance. It is the responsibility of those who are charged with the preparation of a plan for financing to devise a method which will produce the least possible burden upon the taxpayers and users. It is advantageous to arrange early in the proceedings for the employment of a bond attorney to assist the local City Solicitor in the preparation of ordinances and other documents. The importance of securing proper legal advice cannot be stressed too strongly. Many pitfalls will be avoided if this procedure is followed.

Special Assessments

It is also very important that a sewer assessment ordinance be carefully prepared. In Pennsylvania, for instance, this ordinance should contain a detailed description of the location of each individual sewer line by streets, a description of all rights-of-way for the sewer lines, a description of sites for pumping stations and the sewage treatment plant, and the authorization for the municipality to make and enter into contracts on the part of the municipality for the construction work. A sewer assessment ordinance should further provide that the cost and expenses of the collection system be paid by the assessment of the amount of such costs as a charge upon the properties abutting upon the sewers, if such procedure is adopted. In the case of corner lots, the ordinance should set forth the method of assessing such properties where sewers are constructed on both sides of the corner. It is customary to allow a 100-foot exemption on the long side. The method of assessing irregularly shaped properties should be completely covered in a sewer assessment ordinance and should be fair. It is necessary to state further in a sewer assessment ordinance that, immediately upon the completion of the sewer system, the engineers should ascertain the exact cost of that portion of the system which is assessable against the adjoining properties.

A section of the ordinance is devoted to the payment of assessment bills, and it usually states that the proceeds from the assessments are to be retained by the treasurer in a sinking fund to be applied in payment of the principal and interest on the assessment bonds. Should an owner of a property against which an assessment is made neglect to pay the assessment within a definite time period, such as 30 days after it becomes due, the municipality should then file a claim, together with a penalty of, say, 5 or 6 per cent plus the interest on the principal, and it then becomes the duty of the municipal attorney to file a lien against the property.

It may be well to point out the pit-

falls in the preparation of sewer assessment lists. In order that a sewer assessment may be properly prepared, it is necessary to make a search of the titles of the properties to ascertain the names of the property owners and also the front footage upon which the assessment is to be based. Complete plans of all assessable properties should be prepared, showing the location and size of all properties, together with the assessable frontage and the location of the sewer lines. Care should be exercised in the preparation of these plans so that their accuracy cannot be questioned.

Revenue Bonds

The methods utilized in arranging for the financing of a sewage system with revenue bonds, whether it be direct by the municipality or by an independent organization, will be practically the same. The preliminary steps will be similar to the methods employed if general obligation or sewer assessments are utilized. An engineering study must first be made and a plan prepared. The financial phase of the problem must be studied, a bond attorney consulted, and the public educated. This perhaps is of greater importance where revenue bonds are issued than in the case of general obligation bonds. Revenue bonds are somewhat similar to corporate issues.

In order to make revenue bonds saleable, careful engineering estimates and a report must be prepared. These estimates must show accurate data on the costs of construction, operation, maintenance, collecting sewer rentals and depreciation, together with the number of houses and the rate at which the houses will be connected to the sewer system during the early years of development. The annual sewer rental should be sufficient to meet all operation and debt service costs, together with a fund sufficient to establish a margin of safety. It is not safe to establish a margin of safety of less than 10 per cent. Since the revenue to be obtained from sewer rentals is the sole security for the revenue bond, great care is necessary in the preparation of estimates.

It is necessary to establish the sewer rental rates prior to the issuance of bonds in order that the bond purchasers may have full knowledge of the expected revenue. If the charge is to be based on fixture units, then a survey must be made of the fixtures in the municipality. If the rental is to be based on water consumption, then these data must be assembled.

Where a new system is established, careful consideration should be given to what is commonly called the "lag" in the rate at which the houses will be connected to the system during the development period, and also in the collection of rentals after connections are made. Determination should be made as to whether the service charges are to be made in advance or after. Figure 1 is the result of experience as to the rate of connections to a newly constructed sewer system during normal periods.

At present, however, house connections are made more rapidly if labor is available to carry out the installation. On a recent extension to a previously established sewer system in the Philadelphia Suburban region, 135 houses out of 148, or 91 per cent, were connected to the system within a period of one year. On the same system 60 per cent of the people paid their entire sewer assessments within one year, and this represented 70 per cent of the total money value of all assessments.

Sewer Revenue Methods and Rate Schedules

A fair and equitable rate schedule is necessary for the successful financing of a sewage system, whether it be by general obligation or revenue bonds. Care must be exercised to work out a schedule based on service rendered.

A proper system of charges will make possible a more advantageous sale of revenue bonds, and will relieve the tax levy on the taxpayer in case of general obligation bonds. An inadequate or poorly developed schedule may jeopardize an entire program. The following rate bases have been successfully utilized:

1. Water consumption.
2. Plumbing fixture count.
3. Flat rate.
4. Character of property served (church, school, store, home, number of rooms, etc.).
5. Number of sewer connections.
6. Value of property served.
7. Size of water meter.
8. Volume and character of the sewage or industrial waste.

These methods have been used in combination among themselves and have likewise been used in combination with an *ad valorum* tax on real estate. These eight methods have been modified and combined in the following ways:

(a) A service charge plus metered water consumption.
(b) Graduated schedule of charge based on water consumption.
(c) Combination of assessed valuation and water consumption.
(d) Graduated charge on basis of water consumption, plus an additional charge based on the character of sewage or industrial waste.
(e) Charge based on floor area or the footage of property served.
(f) A rental based on the number of employees in an industry plus a water consumption charge.

Water consumption, fixture count and flat rates appear to be the most popular methods. The procedure varies in different states, however, due to differences in the laws. The Supreme Court of Pennsylvania recently upheld an ordinance of the city of Philadelphia imposing a sewer rental based on varied percentages of the water bills, such percentages reducing with increased water consumption. The court has specifically rejected a sewer rate based upon the value of the property served.

In Florida, monthly minimum charges are graduated, with the small individual home at a normal rate and the larger building and larger water users at a higher rate. Experience in Florida is that municipal ownership of water utilities provides a practical method of billing the sewer charge.

In Oregon, the two most common methods of charging for sewer service are on the basis of water consumption and flat rates. Collection may be forced by a lien on property or by shutting off water service. The city of Portland adjusts sewer rental for water not reaching sewers and allows for lawn sprinkling by providing charges for the months of June to September not to exceed the monthly average of charges for the previous four months. Most Oregon cities place sewer rental charges on water bills where the water works is municipally owned; this results in a small cost of collection.

Brockton, Massachusetts, appears to be the first city in the country to adopt a sewer rental plan (1894). Sixty per cent of the required operating revenue is from sewer rentals and the remaining 40 per cent is from general taxation.

Buffalo, N. Y., has a two-part rate. Fifty-five per cent of the revenue is obtained from a sewer rental based on water consumption, and the remaining 45 per cent is obtained from a sewer rental based on service to area. This latter charge is distributed and measured on the basis of the assessed valuation.

In Bloomington, Ind., sewer charges are based on a sliding scale on water consumption. Bills are rendered monthly with a minimum of 25 cents per month. By comparison, the sewage

charge is 25 to 35 per cent of the water bill.

In Detroit, a sewage treatment charge is imposed on the basis of water consumption at a uniform rate regardless of the purpose for which used. Water proved not entering the sewers is exempt. The ordinance provides the right to lien unpaid water bills and also to discontinue water service if sewer charges are not paid.

In Coatesville, Pa., the sewage rental is charged at 60 per cent of the water bill. In Media, Pa., it is 40 per cent of the water bill, and at Oxford, Pa., it is 75 per cent of the water bill.

Rental charges on sewers are now made by 18 per cent of all cities over 10,000 population, according to the International City Managers' Association. This organization reports that cities over 250,000 rely almost exclusively upon metered water consumption as the basis of the charge.

Grants-in-Aid

Many municipal officials today anticipate State or Federal aid for the construction of sewage facilities. Generally speaking, most municipalities are able, by means of borrowing capacity, revenue bonds, or by creating a special district or authority, to finance the construction of complete systems or of extensions and enlargements to present systems. Sewer rentals can be used as a means to support the revenue bonds. With a Federal debt reaching such high proportions, it appears doubtful if Federal aid will be made available, except during times of great unemployment. On the other hand, the state and municipal debts are lower now than before the war.

Some states have made arrangements for grants to aid in financing preparation of plans for municipal improvements. The government, through the Federal Works Administration, will also make non-interest bearing loans for plan preparation.

Effect of Increased Construction Costs and Decreased Bond Issue Rates on Financing Sewage Systems

Howson, in his paper "Future Costs and Their Effects on Engineering Budgets" (ASCE *Proceedings*, **72**, 3, 337; March, 1946), stated:

"Engineers should be realistic. Postwar construction costs are bound to be materially higher than prewar. In most lines of general construction the increase above 1940 will probably approximate 50% by 1950, and in certain classes of construction such as pipe lines and sewers involving a large proportion of common labor, the increase will be materially higher."

The author has handled two small sewer extensions in the Philadelphia area, each comprising approximately 2½ miles of sanitary sewers. The increase in the cost of installing these sewers from 1943 to September, 1946 was 32 per cent.

For the past twelve years the general trend of municipal bond interest rates has been downward, and during the early part of 1946 they attained the lowest rate on record. From the standpoint of municipal finance, this means that the interest rate at which municipal bodies can borrow money is favorable. How great this change in the cost of money to municipalities has been in the recent past is illustrated in Figure 2. An index of 100 municipal bonds throughout the country during 1945 showed an average yield of 1.47 per cent, as compared with an average yield of 4.15 per cent for the decade 1922–1931, and of approximately 5.29 per cent in 1933. This is a decided change in the market status of municipal credit and it means that our local governmental bodies can finance projects at a cheaper interest rate than ever before.

How long this situation will exist is problematical and can best be analyzed when consideration is given to the factors which have produced the present

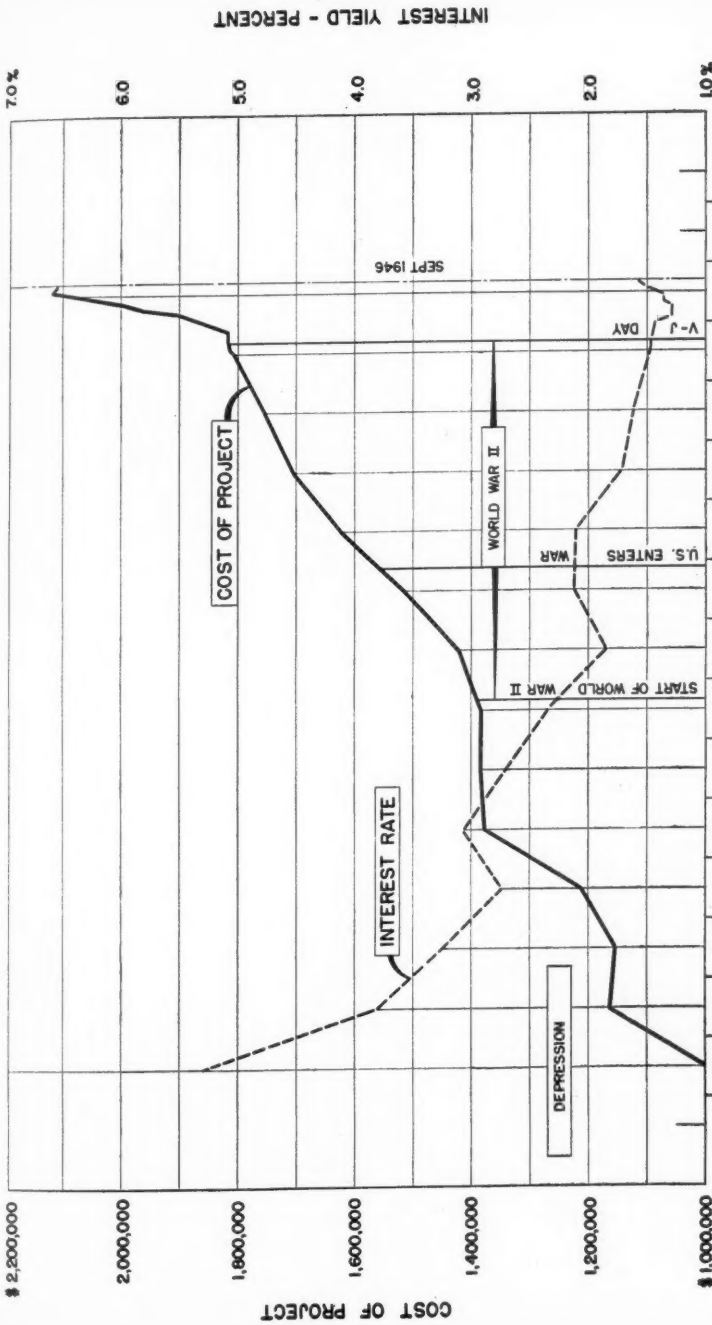

FIGURE 2.—Relation between cost of construction and rate of interest on municipal bonds during period 1933–1946.

Note: Construction cost is based upon a project costing $1,000,000 in 1933 with variation in cost from 1933 to 1946 based on Engineering News Record Construction Cost Index. Interest rates are based upon the average yield of 100 municipal bonds throughout the country for the period 1933–1945 and on the *Bond Buyer's Index* for months January 1946 to September 1946 inclusive.

level of municipal bond prices. They are:

(a) The general downward movement in interest rates,

(b) The increased importance of the tax-exempt feature of municipal bonds,

(c) The improved financial condition of many municipalities, and

(d) Debt reduction in municipalities and a smaller volume of new issues of municipal bonds which have been available in the market during the war.

When consideration is given to the relation between construction costs and interest rates on municipal bonds it will be evident that the cost of constructing sewage facilities in a municipality should be stated in terms of annual debt service requirements rather than in terms of construction costs. After all, it is the annual cost to the property owner which counts, and the cost to each individual must be determined by considering both the construction cost and the interest rate on the borrowed money.

A study has been made by the author of the effect of the increased construction costs and decreased bond interest rates on financing sewer systems and sewage treatment facilities. The country is now faced with construction costs (September, 1946) which are 111.6 per cent higher than they were in 1933, and 49 per cent higher than in 1940. However, the interest rates on municipal bonds are low today and with this lower rate, the annual amortization cost or debt service has not increased in proportion to the construction cost. (See Figure 2, a curve showing the relation between construction cost and rate of interest on municipal bonds for the period 1933 to 1946.)

In Tables I, II and III are presented the annual amortization costs for issues of 20, 30 and 40 year serial bonds to finance a construction cost of $1,000,000, based on 1933 construction prices, with variations in the size of bond issues for the succeeding years up to 1946 calculated from the *Engineering News-Record* Construction Cost Index. In the preparation of these tables average interest rates and yields of 100 municipal bonds throughout the country were used.

Figure 3 shows the annual amortization cost requirements, including interest and sinking funds for supporting 20, 30 and 40 year bonds during the period 1933 to 1946, inclusive.

Figure 4 shows the relation between construction costs for the period 1933

TABLE I.—Annual Amortization Cost for an Issue of 20-Year Serial Bonds to Finance a Construction Cost of $1,000,000 Based on 1933 Prices, with Variations in the Size of the Bond Issues for Years 1933 to 1946 Calculated from Engineering News-Record Construction Cost Index

Year	Construction Cost ENR Index (1913 =100)	Construction Cost of Project	Average Bond Yield[1] (%)	Rate of Amortization[2] (20 Years)	Annual Total Amortization (20 Years)
1946	360.19[3]	$2,116,523	1.58[4]	$0.0587	$124,200
1945	307.74	1,808,320	1.47	0.0581	105,100
1944	298.64	1,754,850	1.61	0.0589	103,400
1943	289.95	1,703,780	1.71	0.0595	101,400
1942	276.31	1,623,630	2.10	0.0617	100,200
1941	257.84	1,515,100	2.12	0.6190	93,800
1940	241.96	1,421,780	1.85	0.0603	85,700
1939	235.51	1,383,890	2.34	0.0632	88,500
1938	235.86	1,385,950	2.68	0.0653	90,700
1937	234.71	1,379,190	3.07	0.0677	93,400
1936	206.42	1,212,950	2.73	0.0655	79,400
1935	196.44	1,154,310	3.24	0.0687	79,300
1934	198.10	1,164,060	3.82	0.0724	84,300
1933	170.18	1,000,000	5.29	0.0822	82,200

Amortization Costs—Per Cent of 1933 Costs

1946 = 151.1%	1939 = 107.7%
1945 = 127.9%	1938 = 110.3%
1944 = 125.8%	1937 = 113.6%
1943 = 123.3%	1936 = 96.6%
1942 = 121.9%	1935 = 96.5%
1941 = 114.1%	1934 = 102.5%
1940 = 104.3%	1933 = 100.0%

[1] From Chemical Bank & Trust Co. Publication entitled, "A Thirteen Year Comparison of Prices and Yields of State and Municipal Bonds." Average of 100 bonds listed.

[2] From Robinsonian Amortization Tables—Period 20 years.

[3] ENR Construction Cost Index as of Sept. 1, 1946.

[4] Yield of bonds as of Sept. 1, 1946, from *Bond Buyer's Index.*

TABLE II.—Annual Amortization Cost for an Issue of 30-Year Serial Bonds to Finance a Construction Cost of $1,000,000 Based on 1933 Prices, with Variations in the Size of the Bond Issues for Years 1933 to 1946 Calculated from Engineering News-Record Construction Cost Index

Year	Construction Cost ENR Index (1913 =100)	Construction Cost of Project	Average Bond Yield[1] (%)	Rate of Amortization[2] (30 Years)	Annual Total Amortization (30 Years)
1946	360.19[3]	$2,116,523	1.58[4]	$0.0421	$89,100
1945	307.74	1,808,320	1.47	0.0416	75,200
1944	298.64	1,754,850	1.61	0.0423	74,200
1943	289.95	1,703,780	1.71	0.0429	73,200
1942	276.31	1,623,630	2.10	0.0453	73,600
1941	257.84	1,515,100	2.12	0.0454	68,800
1940	241.96	1,421,780	1.85	0.0437	62,100
1939	235.51	1,383,890	2.34	0.04685	64,800
1938	235.86	1,385,950	2.68	0.04895	67,800
1937	234.71	1,379,190	3.07	0.0515	71,000
1936	206.42	1,212,950	2.73	0.0493	59,800
1935	196.44	1,154,310	3.24	0.0526	60,700
1934	198.10	1,164,060	3.82	0.0566	65,900
1933	170.18	1,000,000	5.29	0.0672	67,200

Amortization Costs—Per Cent of 1933 Costs

1946 = 132.6%	1939 = 96.4%
1945 = 111.9%	1938 = 100.9%
1944 = 110.4%	1937 = 105.7%
1943 = 108.9%	1936 = 89.0%
1942 = 109.5%	1935 = 90.3%
1941 = 102.4%	1934 = 98.1%
1940 = 92.4%	1933 = 100.0%

[1] From Chemical Bank & Trust Co. Publication entitled, "A Thirteen Year Comparison of Prices and Yields of State and Municipal Bonds." Average of 100 bonds listed.

[2] From Robinsonian Amortization Tables—Period 30 years.

[3] ENR Construction Cost Index as of Sept. 1, 1946.

[4] Yield of bonds as of Sept. 1, 1946, from *Bond Buyer's Index.*

TABLE III.—Annual Amortization Cost for an Issue of 40-Year Serial Bonds to Finance a Construction Cost of $1,000,000 Based on 1933 Prices, with Variations in the Size of the Bond Issues for Years 1933 to 1946 Calculated from Engineering News-Record Construction Cost Index

Year	Construction Cost ENR Index (1913 =100)	Construction Cost of Project	Average Bond Yield[1] (%)	Rate of Amortization[2] (40 Years)	Annual Total Amortization (40 Years)
1946	360.19[3]	$2,116,523	1.58[4]	$.0339	$71,700
1945	307.74	1,808,320	1.47	.0332	60,000
1944	298.64	1,754,850	1.61	.0341	59,800
1943	289.95	1,703,780	1.71	.03475	59,200
1942	276.31	1,623,630	2.10	.0372	60,400
1941	257.84	1,515,100	2.12	.03735	56,600
1940	241.96	1,421,780	1.85	.0356	50,600
1939	235.51	1,383,890	2.34	.0387	53,600
1938	235.86	1,385,950	2.68	.0411	57,000
1937	234.71	1,379,190	3.07	.0438	60,400
1936	206.42	1,212,950	2.73	.0415	50,300
1935	196.44	1,154,310	3.24	.0448	51,700
1934	198.10	1,164,060	3.82	.0492	57,300
1933	170.18	1,000,000	5.29	.0606	60,600

Amortization Costs—Per Cent of 1933 Costs

1946 = 118.4%	1939 = 88.4%
1945 = 99.0%	1938 = 94.1%
1944 = 98.7%	1937 = 99.7%
1943 = 97.7%	1936 = 83.0%
1942 = 99.7%	1935 = 85.3%
1941 = 93.4%	1934 = 94.6%
1940 = 83.5%	1933 = 100.0%

[1] From Chemical Bank & Trust Co. Publication entitled, "A Thirteen Year Comparison of Prices and Yields of State and Municipal Bonds." Average of 100 bonds listed.

[2] From Robinsonian Amortization Tables—Period 40 years.

[3] ENR Construction Cost Index as of Sept. 1, 1946.

[4] Yield of bond as of Sept. 1, 1946, from *Bond Buyer's Index.*

to 1946, inclusive, and the annual amortization costs for 20, 30 and 40 year bonds. The following tabulation reflects the relationship between increased construction costs and reduced interest rates on municipal bonds:

	Relation Between 1933 and Sept., 1946	Relation Between 1940 and Sept., 1946	Relation Between 1933 and 1945	Relation Between 1940 and 1945
Per cent rise in construction cost	111.6	49.0	80.8	27.0
Per cent rise in amortization cost using 20-year bonds	51.1	45.0	27.9	22.9
Per cent rise in amortization cost using 30-year bonds	32.6	43.6	11.9	21.0
Per cent change in amortization cost using 40-yr. bonds	18.4	41.7	−1.0	18.6

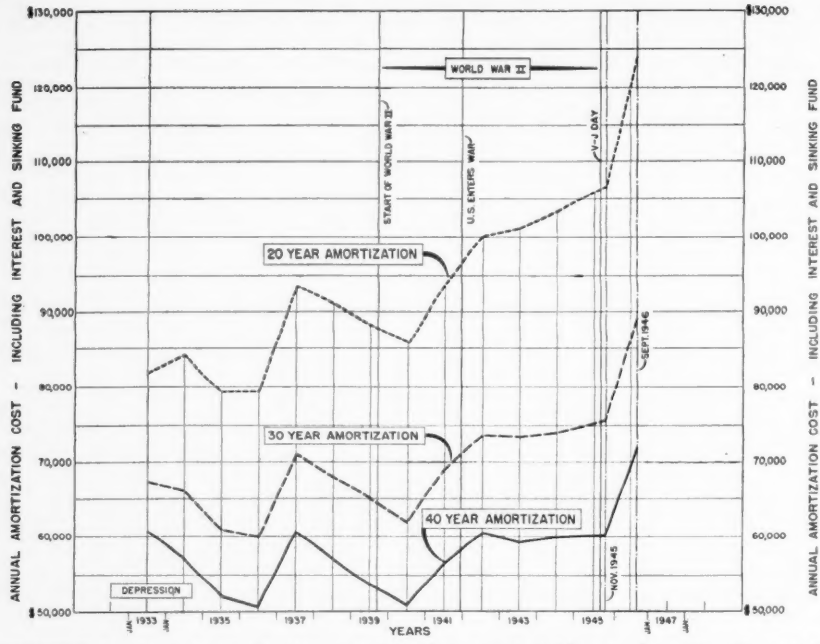

FIGURE 3.—Annual amortization cost for interest and sinking fund on 20-, 30- and 40-year municipal bonds during period 1933–1946.

Note: Annual amortization cost is for an issue of serial bonds to finance a construction cost of $1,000,000 based on 1933 prices with variations in the size of the bond issues for years 1933 to 1946 calculated from the Engineering News Record Construction Cost Index.

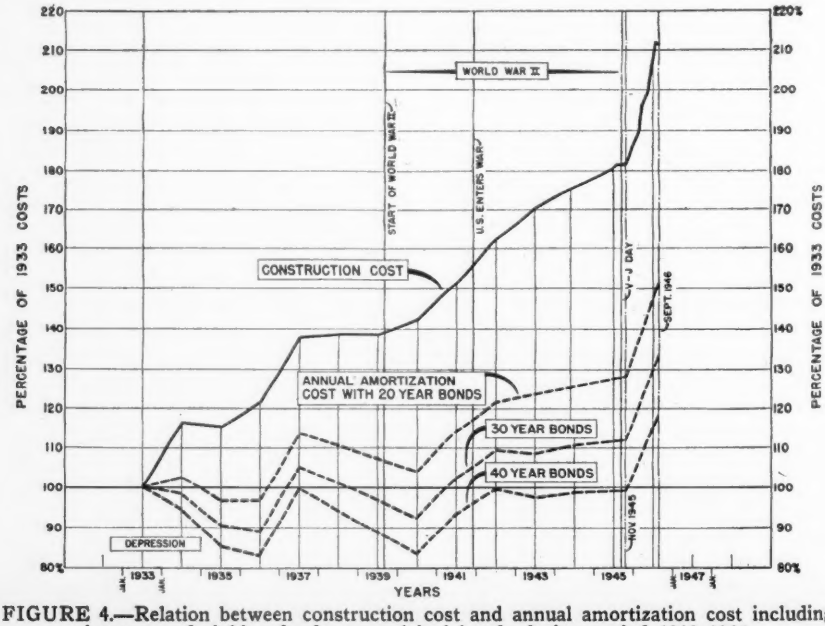

FIGURE 4.—Relation between construction cost and annual amortization cost including interest and sinking fund on municipal bonds during period 1933–1946.

Note: Annual amortization cost is for an issue of serial bonds to finance a construction cost of $1,000,000 based on 1933 prices with variations in the size of the bond issues for years 1933 to 1946 calculated from the Engineering News Record Construction Cost Index.

TABLE IV.—Common Methods Used for Financing Sewage Works Construction

State	General Obligation Bonds	Special Assessment Bonds	Specia Assessments	Basis of Assessments	*Ad Valorem* Levies or Revenue from Other Utilities	Revenue Bonds	Are Rev. Bonds Non-Debt?	Do They Create Lien?
Alabama	Yes	Yes	—	Ft. front and area	Not usually pledged	Yes	Yes	No
Arkansas	Yes	—	—	—	Yes	Yes	—	No
California	Yes	Yes	Yes	Benefit or ft. front	Very seldom	Authorized	Yes	—
Colorado	Yes	Yes	—	—	—	Sewer rental bonds	—	Yes
Connecticut	Usual	—	Yes	Ft. front or area	—	Authorized by law, little used	—	No
Delaware	All but 3	3	—	—	In 2 cases	None	—	—
Florida	Yes	Yes	—	—	Yes	Mortgage revenue certificates	Yes	No
Georgia	Yes	Yes	Yes	Ft. front	Yes	Yes	Yes	No
Idaho	Yes	—	Yes	Ft. front	No	No	—	—
Illinois	1/3	<3%	Occasional short sewer extensions	Ft. front	Illegal other than general fund	44% either sewer revenue or water and sew. rev. bds.	Yes	Yes
Indiana	Yes	Yes	—	—	—	Extensively	Yes	No
Iowa	Universal	—	Universal	Ft. front or prop. value	None—if excess revenue used it requires transfer of bonds	Limited use	Yes	No
Kentucky	Yes	Yes	Yes	Ft. front	In a few cases	Yes	Yes	No
Louisiana	Yes	—	—	—	Rare—transfer through general fund	Yes	Yes	Yes
Maine	Yes	—	Yes	Per bldg.	No	In districts only	Yes	Yes
Maryland	Yes	Yes	Yes	Ft. front	*Ad valorem*	Yes	Yes	Yes
Massachusetts	Yes	—	Yes	Ft. front	—	None	—	—
Michigan	Yes	Yes	Yes	Benefits	Occasionally	Yes	Yes	No
Minnesota	Yes	Yes	Yes	—	A few cases	Authorized	Yes	Yes
Mississippi	Most used	Permitted but not used	—	—	—	Some—tied in with water revenue	Yes	No

TABLE IV (cont.).—Common Methods Used for Financing Sewage Works Construction

State	General Obligation Bonds	Special Assessment Bonds	Special Assessments	Basis of Assessments	*Ad Valorem* Levies or Revenue from Other Utilities	Revenue Bonds	Are Rev. Bonds Non-Debt?	Do They Create Lien?
Montana	Yes	Yes	Yes	Area or ft. front	—	Yes	Yes	No
Nebraska	Yes	Yes	Yes	Ft. front	—	Very few	—	No
Nevada	Yes	Yes	Yes	Property value	*Ad valorem*	—	—	—
New Jersey	Yes	Yes	—	—	—	Yes	Yes	Yes
New York	Yes	Yes	Yes	Benefits	Yes	Authorized but not used	Yes	Yes
North Carolina	Yes	—	Yes	—	Yes	Yes	—	—
Ohio	—	—	—	—	—	Yes (mortgage)	Yes	No
Oklahoma	Yes	—	Usually for extensions	Abutting property	—	Not authorized	—	—
Oregon	Yes	Yes	Yes	—	—	Yes	Yes	—
Pennsylvania	Yes	Yes	Yes	Ft. front or benefits	Authorized	Yes	Yes	No
Rhode Island	Yes	—	Yes	Generally ft. front	—	—	—	—
South Dakota	Treatment plant and outfall sewers	—	Lateral sewers	Ft. front	By few municipalities for major construction	Yes	Yes	No
Tennessee	—	—	—	—	—	Yes	—	—
Texas	Yes	Yes	Doubtful	—	No	Yes	—	No
Utah	Yes	Yes	—	Ft. front	—	Yes	No	No
Vermont	Yes	—	—	—	—	—	—	—
Virginia	Most used	—	Few	—	Mostly for extensions and improvements	Yes	Yes	No
West Virginia	Yes	—	Yes	Ft. front	No	Principal method	Yes	Yes
Wisconsin	Yes	Yes	Yes	Ft. front or benefits	No	Yes	Yes	No
Wyoming	Yes	Authorized but sale difficult	Yes	Area served	—	Yes	Yes	No

TABLE V.—Special Administrative Units Other than Municipal Governing Bodies

State	Authorities, Sanitary Districts, Sanitary Commissions	How Created	How Composed	Powers of Official Board	Other Methods	Functional Limitations	Experience
Alabama	All three	Appointed by city officials	Usually 3 to 5 members	Full authority	—	—	Satisfactory, costs compare favorably with other methods
Arkansas	Yes	Vote of majority of property owners	—	Construct and maintain system	—	—	—
California	(1) Sanitary dist. (2) Sanitation dist. (3) Sewer maintenance dist.	(1) By election, (2 and 3) Bd. of supervisors	—	(2) Trunk sewers and disposal only	Public utility districts	Sew. rev. bds. int. <6%, term <40 years. Work over $500 by contract	Public utility districts have no power to enforce connection. Costs comparable
Colorado	Sanitary district or municipality	By qualified voters	—	Make assessments; shut off water	—	—	—
Connecticut	Town, city, borough or sewer district	By Legislature	Varies	Management of system	—	—	—
Delaware	New Castle San. Dist. only	Legislative Act; petition and election	—	—	—	—	—
Florida	—	—	—	—	Municipality may by ordinance create a zone and require connection	Bonds (mort. rev.) must sell at 95% par. Int. <6%	Rev. certificates sell at low interest rates
Georgia	Yes	Sponsored usually by city or county	Local citizens	Issue rev. cert.; execute construction	—	—	—
Idaho	—	—	—	—	Special council created body	—	—
Illinois	Sanitary districts	Petition to county judges and majority vote	Depending on Act, 3 to 9 Trustees	Manage and contro district	Combinations of g.o.b., sew. rev. bds., gen. funds, sew. rental charges	Very flexible but subject to debt limitations except in rev. bds.	Generally good, sew. rev. bds. and san. districts most popular. Costs likely lower
Indiana	Sanitary districts	By city ordinance	City eng., 2 mayors appointment (one on nomination of state bd.)	—	Special taxing district bonds serviced by taxes levied on property within the district—non-debt	Rev. bonds not over 40 years	—
Iowa	One sanitary district	By vote of people	Incorporated within any well-defined boundaries containing at least one incorporated city or town	Absolute in utility, and financing same	Limited levy bonds included under 5% debt limit—rarely used	—	—
Kentucky	Sanitary districts	Petition to State Commissioner of San. Districts	Appointed by county judge	Eminent domain, but subject to state health dept.	—	Subject to requirements of state dept. of health	Only 1 organized and 1 in process
Louisiana	Sanitary districts	By governing body of the county	Appointed by same body	Issues revenue bonds	Separate corporate agency as at New Orleans	Bonded debt not to exceed 10% of valuation (40-year retirement)	—
Maine	Sewerage districts	By state Legislature	Given area in a given city or town	Borrow to construct, and levy assessments to pay bonds, operating expenses and improvements	—	Limited to the extent of the area served	No sewer district in state has defaulted on bonds
Maryland	Sanitary districts	By act of Legislature	Appointed by Governor or county commissioners	Establish assess. and chgs. to pay const. and operation	County, municipality or san. dist. may raise not exceeding 2% of taxable basis	Orders of state board of health	—
Massachusetts	Sanitary districts	By act of Legislature	Chairman appointed by Governor, other members according to Act	Full	—	—	—
Michigan	Metropolitan districts—authorized but not used	—	Two or more units of government.	Levy and collect taxes, rents, tolls, special assessments	Municipalities may enter contract with other municipalities for such service	Statutory limit on g.o. and s.a. bonds and borrowing power—2% of assessed value. All issues must be approved by state mun. fin. com.	—

TABLE V (cont.).—Special Administrative Units Other than Municipal Governing Bodies

State	Authorities, Sanitary Districts, Sanitary Commissions	How Created	How Composed	Powers of Official Board	Other Methods	Functional Limitations	Experience
Minnesota	Minn.-St. Paul San. Dist.	By Legislative Act	Each city represented	Finance by general levy or service charges	—	—	—
Mississippi	None	—	—	—	—	—	—
Montana	—	—	—	—	City Council only	—	—
Nebraska	Sanitary districts	Resolution of governing body	—	—	—	—	Good
New Jersey	Authority	By resolution of governing body, county, municipality or two or more municipalities	Appropriate number members appointed by each municipality	Issue own non-debt rev. bonds or sell negotiable bonds issued by mun.	—	—	—
New York	Authority (Buffalo); Sewer districts	Special leg. Act; gen. oblig. bonds of town paid by special assessments	Board appointed by mayor	—	Municipality may place surpluses, unexpended bal. or approp. in reserve to accumulate reserve to finance construction	—	Authority satisfactory; no difficulties; bonds sell at par at interest under 6%
North Carolina	Sanitary districts	By state board of health under state statute	Three-man board elected by popular vote	Corporate powers as relates to water supply, sewage wks., garbage disp.	—	Bonded debt non-revenue utilities may not exceed 8% property valuation	Satisfactory, and at reasonable cost
Ohio	—	—	—	—	Sewerage depts. set up by law. Councils establish rentals	—	—
Oregon	—	—	—	—	—	Limit of non-debt not to exceed 5% of assessed value after deducting any sinking fund. 30-yr. max. and 6% interest	—
Pennsylvania	Municipal or joint authorities	One or more municipality file articles and Board Members' names with Sec. of State, who issues Cert. of Incorporation	Five members appointed by municipality creating	Collect charges, issue revenue bonds	Franchise to privately owned sewage corp. Special tax not to exceed 2 mills	Bond maturity limit 40 years	—
South Dakota	None	—	—	—	—	—	—
Tennessee	Utility districts	Petition and hearing; incorporated by Sec. of State	County judge appoints three to self-perpetuating Board	Collect charges, incur debt, issue negotiable revenue bonds	—	Bond maturity limited to 40 years	—
Texas	Districts	Legislative statute	—	—	—	—	—
Virginia	Yes	Court order on petition of citizens	Board of Supervisors of a single county or by commission appointed by Governor	Issue revenue bonds	W.P.A. used extensively during life	San. dist. in single county cannot issue gen. oblig. bds. over 18% assessed valuation of district	—
West Virginia	Sanitary board	Appointed by council	Mayor, registered engineer and business man.	Complete except issuing bonds —power of Council	—	—	Good
Wisconsin	Town sanitary districts	Petition of 60% owners; created by Town Board	Appointment by Town Board	Provide any improvements in sanitation and make regulations	Metropolitan sewerage commission—created by county court on petition. Appointed by judge	General oblig. bd. limit 5% of assessed value. Ft. front limit $2.00 on each side street. No limit on revenue bonds	Satisfactory
Wyoming	—	—	—	—	—	Revenue bds. require general election. G.O. bds. for sewers limited to 4% assessed valuation	Satisfactory
Nevada	"Improvement district"	Petition and election	Property owners benefited	Supervise, operate and recommend. Assessments must be approved by county commissioners	—	—	—

TABLE VI.—Bases of Rentals and Charges Used in Various States

State	Water Consumption	No. of Plumbing Fixtures	No. of Sewer Connections per Dwelling	Flat Rate	Type of Property	Metered Sewage	Two- or Three-Part Rates
Alabama	Occasional	Most common	Occasional	Occasional	—	—	—
Arkansas	Most used	Yes	Yes	Yes	—	None	—
California	Yes	—	—	—	Yes	—	Yes
Colorado	—	—	—	Yes	Yes	—	—
Connecticut	Little used	—	—	—	—	—	—
Florida	Yes	—	—	Yes	—	—	—
Georgia	Yes	Yes	—	Yes	—	—	—
Illinois	50%	2%	2%	20%	5%	—	20% type property plus water consumption
Indiana	Yes	—	—	—	Yes	And industrial waste	—
Iowa	Yes	—	—	Yes	—	—	—
Kentucky	Yes	Yes	Yes	Yes	—	Yes	—
Louisiana	—	—	—	Yes	—	—	—
Maine	Yes	—	Yes	Yes	—	—	—
Maryland	Yes	Yes	—	Yes	Yes	—	—
Massachusetts	At least 1 case	—	—	—	—	Some industries	—
Michigan	Chiefly	Occasionally	—	—	—	Few instances	—
Minnesota	Yes	—	—	Yes	—	Char. of sewage	Flat chgs. and water cons.
Mississippi	Yes	—	—	Yes	Yes	—	—
Montana	Yes	—	—	—	—	—	—
Nebraska	—	—	—	(only 3 cases)	—	—	—
New Jersey	Yes	Yes	Yes	—	—	—	—
New York	Yes	—	—	—	Yes	—	—
North Carolina	Yes	—	—	Yes	—	—	—
Ohio	43% (Plus minimum charge)	Yes	—	Yes	Yes	—	—
Oklahoma	—	Yes	—	Yes	Yes	—	—
Oregon	42%	8%	—	50%	—	—	—
Pennsylvania	Yes	Yes	—	Yes	—	Yes	—
Texas	Yes	Yes	Yes	Yes	Yes	—	—
Virginia	Yes	Yes	Yes	Most used	Yes	—	—
West Virginia	Principal method	—	—	Yes	—	—	—
Wisconsin	Yes	Yes	—	Yes	—	Yes	Yes
Wyoming	—	—	—	Almost exclusively	—	—	—

During the period 1933 to 1946 construction costs increased 111.6 per cent, whereas the rise in amortization cost on 30-year bonds during the same period was only 32.6 per cent. Between 1940 and 1946 construction costs increased 49 per cent while on the other hand the amortization cost on 30-year bonds increased only 43.6 per cent.

General Data on Sewage Works Financing

Tables IV, V, and VI contain miscellaneous data regarding the sewage financing methods used throughout

the United States. These data were obtained chiefly from replies to questionnaires and supplementary information furnished by the various state sanitary engineers. The data contained in these tables are summarized herewith:

(1) Financing methods used by municipalities or special administrative units:

	Number of States	Per Cent of 40 States Reporting
General obligation bonds are used in	38	95
Special assessment bonds are used in	23	58
Special assessments are used in	26	65
Total using special assessments, with or without bonds	34	85
Ad valorem levies or revenues of other utilities such as water, electric, gas, etc., are used in	19	48
Revenue bonds are used in	30	75

Notes:

(a) Revenue bonds are authorized by law in three states in addition to the above.

(b) Revenue bonds are "non-debt" in 25 states.

(c) Revenue bonds create a lien on real estate in 9 states and do not create a lien on real estate in 20 states.

(d) Revenue bonds are a mortgage on the property of the sewage works in 2 additional states.

(2) Bases of assessments used in 23 states:

	Number of States	Per Cent of 23 States Reporting
Foot front	18	78
Benefits	5	22
Area of lot	4	17
Property value	2	8
Per building	1	4

(3) Special administrative units (authorities, sanitary districts, sanitation commissions, etc.) have been created in 27 states, representing 67 per cent of the 40 states reporting. Such special units are also authorized by law in one other state.

(4) Bases of service or rental charges commonly used in various states are as follows:

	Number of States	Per Cent of 40 States Reporting
Water consumption	27	68
Flat rate	24	60
Number of plumbing fixtures	15	38
Type of property	11	28
Number of sewer connections	8	20
Metered sewage	7	18
Two- or three-part charges	4	10
No rental charges	4	10

In 1932 Childs and Schroepfer reported that 26 states had either passed sewer rental laws or their constitutions were such that charges could legally be made. Today, of 40 states on which the author has information, rentals are being collected in 36, or 90 per cent.

Conclusions

There appears to be ample means available today for a municipality to finance the construction of sewer systems and sewage treatment facilities. The creation of a special administrative district or commission has been the solution for many municipalities with limited borrowing capacities. With the benefit of experience with revenue bonds throughout the United States, sound methods are now available for most municipalities to construct new sewage works and to improve existing facilities.

If a municipality has sufficient borrowing capacity to issue general obligation bonds, it can proceed without question. Municipal debt limitations can be circumvented by the use of revenue bonds in some states and by the establishment of separate corporate organizations under the laws of other states. Revenue bonds have been gaining in popularity but have not been used to the extent justified because of the lack of legislation in some instances, and because of the lack of experience with this method of financing in others. The trend today is toward use of revenue bonds and

toward the establishment of sanitary districts, commissions or authorities.

Sewer rentals based on water consumption appear to be the most popular. The collection of sewer rentals on water bills is favored by municipalities owning water works systems. Joint sewage projects embracing drainage areas and disregarding political boundaries have gained in popularity.

The cost of constructing sewage facilities in a municipality should be stated in terms of "annual debt service requirements" rather than in terms of construction costs.

Acknowledgments

The assistance rendered by the engineering staff of Albright and Friel, Inc., in assembling data for the preparation of this paper, is gratefully acknowledged. The author is also appreciative of the courtesy extended by the state sanitary engineers who supplied the data presented in Tables IV, V and VI.

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FINANCING SEWAGE WORKS—A DISCUSSION

By F. M. Veatch

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Mr. Friel has given an excellent outline of the methods of financing sewage works improvements, and it is interesting to note the variation of thought—as evidenced by the difference in state laws, in regard to this subject.

One is forced to wonder why something that is good in New York cannot be equally good in California, and to reach the conclusion that some state legislatures have not seen the entire problem. The present status of the revenue law in Pennsylvania, as described by Mr. Friel, is an example of a rather general need for legislation to clarify the situation, since the value of a law is certainly questionable if bonds, issued under its authority, cannot be sold.

Mr. Friel's analysis of the current situation, particularly as regards the combined effect of the high costs of construction and the low costs of financing, is worthy of careful study. As he has pointed out, there "Appears to be ample means for financing construction," and his statement that "A fair and equitable rate schedule is necessary for the successful financing of a sewer system, whether it be by general obligation or revenue bonds" seems particularly appropriate.

There is little doubt that the general idea of paying for sewers and sewage disposal, in terms of service rendered rather than as mere structural units, should be attractive. It should be attractive to the governing bodies of cities since it removes sewer costs from the mounting list of expenses that must be paid from taxes. The demand for public services has increased to the point that the fixed tax levies are commonly inadequate, and the choice lies between limited service or obtaining additional revenue. It is a well known fact that ways and means of securing revenue, from sources other than taxes, is a major objective of at least one country-wide organization of municipal officials.

Due to the inherent economy of suitable methods of financing, the plan usually has actual economy as well as tax relief in its favor. The idea of sewer service charges is attractive to the public, as soon as it is fully understood, since it offers a far more equitable method of distributing costs than has been possible with *ad valorem* taxes. The current popularity of the plan of selling water on the basis of actual use is a case in point and, while the sale of sewer service differs in some detail, it is believed that the basic problem is similar.

Charges for sewer service are attractive to health authorities since they offer assurance that sewers and sewage treatment, when once adopted, will be continued under favorable conditions of operation and maintenance.

Finally, the plan is attractive to those who are responsible for the operation of the systems, since it offers a reasonable chance of attaining the results for which the system was built.

The increasing popularity of "sewer

rentals'' or ''sewer charges'' is evidenced by the number of cities which have adopted the plan. A particularly illuminating discussion of the basic reasons for the general policy of sewer rates is given by W. R. LaDue in his article on ''The Ohio Plan for Financing Sewage Works Improvements'' (*Jour. A.W.W.A.*, **35**, 323–9; March, 1944).

An outstanding feature of existing rates for sewer service is the seeming lack of uniformity as regards bases and objectives as well as the absence of any common ground for comparison.

Mr. Friel has mentioned eight criteria in current use as bases for sewer service charges. It is believed that his list is practically complete, so far as existing rates are concerned, and it is interesting to note that the use of a rate base predicated on investment in the property used and useful in service is not mentioned. The determination of rates based on the cost of service is also not mentioned. These are recognized factors in rate making and there is cause to wonder why they have not been considered in the making of rates for sewer service.

In this respect, there seems to be a remarkably clear analogy between the current situation in the sewage works field and that which existed in the fields of electricity, water and gas possibly a half century ago. The last-named utilities, through years of effort, have evolved systems of rate making which are generally acceptable, and it appears that the time is about ripe for determined effort in the sewage field. Regardless of what a sewer rate is called, its adoption means, fundamentally, that the system is to be operated as a revenue-producing utility rather than as an article of public property such as a park.

Very early in the history of rate making for utilities, it was realized that a large part of the costs of service has no relation to the particular commodity sold, and it has been necessary to allocate these costs in various ways in order that they may be distributed among the users in an equable manner. It is believed that this is particularly pertinent in sewer rates since the only difference is that the commodity is being disposed of rather than being furnished. There is no reason why this difference should prevent the determination of proper rates.

Possibly the points just mentioned may be illustrated by a brief review of the schedule of sewer rates recently adopted at Billings, Mont., where it is necessary to separate a system of combined sewers and to construct treatment works. Service to approximately 32,000 people and a capital investment of approximately $700,000 are involved.

It was decided that all of the costs should be recovered in the form of rates, and the schedule of rates, cited below, was designed to accomplish this purpose. The rate is based primarily on the investment in the system, which is $1,200,000 inclusive of the current improvements.

The annual cost of service is estimated to be $95,826, as follows:

Operation and maintenance	$25,172
Bond service	49,000
Depreciation	17,079
Accounting	4,575
Total	$95,826

Ordinarily portions of this total would be allocated to the four accepted classifications of costs of service, namely, capacity, commodity, customer and public, but in this case, and in view the lack of precedent, it was decided to make only two allocations as follows:

Fifty per cent of the cost was considered to be due to the handling of the sewage and was distributed among the users in accordance with the actual usage of water during the four winter months, when such use is a fair measure of the use of the sewers. This will be recognized as similar to the ''commodity cost'' in water rates.

The remaining portion of the cost was considered to be due to the "capacity" of the system and was distributed among the users, in accordance with the opportunity for use, with the size of the water meter as the determining factor.

Bills for sewer service are payable monthly and the amount appears as a separate item on the water bill.

The schedule of rates is as follows:

First	400 cu. ft. (minimum)	$0.75
Next	600 cu. ft.	0.10
Next	10,000 cu. ft.	0.08
Next	40,000 cu. ft.	0.06
Next	50,000 cu. ft.	0.04
Next	100,000 cu. ft.	0.03
All over	200,000 cu. ft.	0.02

The application of these rates to the customer accounts of the water department for the months of February, March, November and December, 1944, is shown in the following tabulation:

Rate Bracket in Units of 100 Cu. Ft.		Number of Accounts	Number of Monthly Bills During Year	Metered Usage in Units of 100 Cu. Ft. During Year	Annual Cost of Service (dollars)	Annual Yield from Rates (dollars)
From	To					
0	4	1,670	20,036	56,372	18,332	15,027
4	10	2,125	25,500	174,824	27,142	26,407
10	20	695	8,356	118,432	11,140	14,070
20	500	417	5,008	295,484	14,978	22,468
500	1,000	6	72	49,676	1,892	2,756
1,000	2,000	5	56	73,104	2,750	3,367
2,000	up	7	84	528,164	19,592	14,002
Total		4,925	59,112	1,296,056	95,826	98,115

It will be noted that the annual yield of the rates is somewhat in excess of the costs of service and that the revenue from the individual brackets is in general conformance with these costs. In this case, the anticipated revenue from very large users has been made low for the reason that it is realized that some of these rates will require adjustment in accordance with the quantity and character of the sewage involved.

The situation at Billings is mentioned here simply for the reason that it represents the application of some of the accepted principles of rate making. The rate schedule is not presented as a model in any sense of the word, and its desirability in any city, other than Billings, Mont., would be entirely coincidental.

There is an urgent need for definite methods of rate making in the field of sewage if rates in this field are to reach the standing of those in other utilities.

It is the writer's personal opinion that the Federation, through one or more of its technical committees, is in position to perform a valuable service by taking this matter in hand and pointing out the principles which underlie the selection of a rate base, the determination of the costs of service and the equable distribution of these costs.

SCUM CONTROL IN DIGESTERS *

By R. S. Rankin

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Scum formation in sludge digesters is a serious problem in a certain percentage of plants. In a larger percentage this problem either is not present, or the operator has learned how to keep it under control.

Scum may be considered a problem in a digester when it interferes with uniform gas production, when it plugs pipe outlets and stops the normal overflow, when it interferes with the withdrawal of tank contents, or when its volume is so great as to reduce materially the available digestion capacity.

In some plants scum may attain a depth of several feet occupying as much as 30 per cent of available capacity and resisting all reasonable efforts to dissipate it. Persistent accumulations, if allowed to remain in a digester, can occasionally do positive damage. For example, when the scum has sealed off or plugged the normal overflow lines, continued pumping of sludge may force dislodgement of the tank cover, as has actually occurred in a few installations. Also, when a scum-laden tank is emptied, the layer may have become so compact that, as it drops with the receding level, it pulls down with it the gas and even the hot water piping with all their supports.

The question naturally arises as to why some plants are continually faced with this problem, and other plants seldom, if ever, experience it. The problem under discussion, incidentally, refers to persistent scum in the digester after routine operation has been established, and not to a temporary foaming condition sometimes occurring during early stages of operation.

* Presented at Nineteenth Annual Meeting, Federation of Sewage Works Associations; Toronto, Ont., Can., October 7–9, 1946.

Causes of Scum Formation

It is known that some types of sewage carry more scum forming materials than others, and any concentration effect of the clarifier sludge removal equipment probably accentuates the scum forming tendencies of the sludge itelf. Scum forming materials that cause trouble in a digester may be classified approximately as follows:

1. Grease and oil products such as:

(a) Waste from meat packing houses, soap factories and kitchens, usually classed as digestible materials.

(b) Wastes of petroleum origin from oil refineries, machine shops, garages and fuel oil tanks, usually classed as indigestible.

2. Mat-forming materials from industrial plants such as:

(a) Fibers from textile mills, hat factories.

(b) Animal hair from tanneries, slaughter houses.

(c) Paunch manure from meat packing houses.

(d) Rinds or skins from fruit packing houses.

3. Miscellaneous indigestible materials such as twigs, milk bottle caps, matches, rags, etc.

4. Gas-buoyed sludge.

Scum of Industrial Origin

Where the scum is due to industrial wastes, the operator has two courses to follow in solving the problem. One is to fight it out at the plant with the hope of eventually overcoming the difficulty. The other and more effective course is to remove the cause at its source. This might seem like a hopeless task to an operator, but it is surprising

to realize how many times it has been done with excellent results.

The smaller the sewage plant, the more likely this method has of success, because in such places the scum producing material usually originates in a single offending industry. At Danbury, Conn., for example, the sewage treatment plant was in perpetual trouble several years ago with a heavy mat of scum in the digester caused by small particles of fur in wastes from local hat factories. The operator had to resort to removal of the manholes and forking this material out of the digester by hand at frequent intervals, and efficient operation was impossible to say the least. Installation of a fine screen by the city and disposal of the screenings elsewhere kept the bulk of this material out of the digester and greatly reduced the problem.

At Sheboygan, Wis., another example may be cited where a local tannery contributed a waste containing a heavy load of hair mixed with lime. While the lime aided sedimentation in the primary treatment plant, by the time the mixture reached the digesters it formed a solid mat of scum and plaster-like sludge. After a few years of this the operator convinced the officials that the plant would not function properly and the result was the installation of a fine screen at the tannery. It solved the scum problem at the sewage plant and enough lime is still present in the sewage to aid sedimentation.

There are many examples of pretreatment of packinghouse wastes by fine screens, as at Cedar Rapids, Iowa, Sioux Falls and Huron, South Dakota, which have kept the major scum forming materials from reaching the city plant. Many canneries have also installed equipment to remove scum forming materials before discharging their waste into the municipal system, and by so doing they have relieved the sewage plant operator of a major job.

These examples result from effective cooperation of industry and city officials and are usually to be found in a smaller community where the industry is a dominant factor, but where it does not require a separate waste treatment plant of its own. Thus, it may be said that the best method of control of scum produced by industrial wastes is to keep the scum forming materials out of the sewage plant.

In larger cities, however, scum producing materials usually find their way into the plant regardless of what the operator or city can do. Even the smaller plants without industrial wastes occasionally have scum producing materials in the sludge, often caused by grease from kitchens. The operators at such plants have a problem which probably cannot be solved by attempting to go to the source. The simplest solution for them is to attack the problem in the plant itself.

Control Measures at the Digester

Scum caused by accumulations of digestible grease and oils can often be eliminated entirely, or conditions greatly improved, by raising the temperature of the digester to 95° or even 100° F. Occasionally, however, when this is attempted in a plain tank, the lower liquid zone heats up but the heat fails to penetrate the scum layer on top. Obviously, the layer must be broken up by some physical means.

One usually effective remedy is to recirculate the digester contents from the bottom to the top, if possible locating the discharge above the scum layer. Incidentally, this operation was covered by process patents now expired.

Where circulation is impossible and no other facilities are available, live steam or hot water injected into the top has been successful. Some operators in despair have even had to resort to breaking up the scum layer with a fork or other tool, working through the digester manhole.

Once the material has been broken

up and thoroughly heated, it is then a matter of keeping it from reforming. This is not too difficult because many operators have had no recurrence of troublesome scum formations, once they have learned how to cope with them. Operators at numerous plants report no scum problems because they do not allow it to form. They may keep it broken down by mechanical means or by circulating pumps of adequate capacity.

Scum may also form from accumulations of miscellaneous materials such as twigs, bottle caps, rags, and other things which fail to digest, no matter how long they are held in the digester. They may form a dense layer and, unless removed with the sludge, eventually they will occupy a major portion of the tank volume. This material is not always a real floating scum, as in some plants it appears to be submerged and buoyed by a denser sludge layer underneath. More than one operator has discovered this layer of material after several years of operation, and the only successful way to remove it has been to empty the tank. This has proved a difficult task and one to be avoided by all possible means. To prevent this condition, the operator should sample his tanks at intervals, and determine whether this undigestible material is present and whether it is increasing in volume. The desirable objective is to withdraw this material with the digested sludge, but this is not always possible because its location is not always known.

Gas-buoyed sludge particles occasionally accumulate to form a dense black scum of considerable depth, even where other types of scum may be absent. The best remedy for this situation is agitation, sufficient to separate or scrub these particles, thereby releasing the entrained gas after which the sludge particle should sink. Digested sludge particles in a dry state have a theoretical specific gravity from 1.4 to 1.6 times that of water, so the tendency to settle is present, if the buoyant forces can be detached from the particles.

Digester Design for Scum Control

So far, all suggestions at control of scum have been directed to the operator, but the operator at best can deal only with the installation as it has been turned over to him. He can make minor changes, of course, but usually he must make the best of what he has and cannot count on making major changes until he has worn himself out trying to make the original layout do. Undoubtedly, he could offer some valuable suggestions to the designing engineer, but this is too late so far as his plant is concerned, and anyway the the engineer usually has to guess at the type of sewage the plant will actually receive because the mixture of sewage reaching the new plant frequently does not even exist before its completion. From the writer's observations, however, possibly a few suggestions on design will serve in bringing about improvements in facilities provided to the operator for coping with this problem.

Scum Removal Piping

The construction of the digester appears to have some bearing on the scum problem. Several years ago, in the construction of single stage fixed cover digesters, it was not uncommon for the engineer to design as a part of the gas take-off manhole near the center, a scum draw-off connection going directly to the sludge bed. The operator had only to open a valve and any accumulated scum was drained off. These digesters were usually equipped with slow moving scum arms which, with the slope of the roof, brought any floating scum to this manhole at the high point.

Many of these plants operated for years with no scum problem which could not be easily handled. This solution seems so simple yet such a design is now practically extinct.

Scum Breakers

Another design factor is the type of roof or cover used on the digester. Two major classes of roof design are commonly used, one in which the cover is submerged, either fixed or floating, and the other in which the cover is not submerged, and this also may be fixed or floating. An example of the latter type is a gasholder, in which the intervening space is filled with gas under pressure.

To cope with the more difficult problems in the submerged type with fixed roof, the slow-moving type of scum breaking equipment, with alternate fixed and moving fingers passing through the scum zone, has proven very effective. These fingers sweep the entire submerged underside of the roof, thereby preventing formation of thick scum layers and assisting in the uniform release of gas. Installations of this type have been in operation for 15 years without the water level ever having been lowered. This type has also been successful in handling scum problems where garbage and sludge are digested together.

Surface Agitation

Where the cover is not submerged and the liquid surface is free, and where the scum forming materials can move laterally without restraint of the roof surface, some form of surface agitation can be effectively applied. Effective surface agitation, however, cannot be secured without expenditure of power, whether it is done by properly designed mechanical mixing or by recirculation pumps. Within limits, the greater the power applied the greater the effectiveness of agitation. It seems more efficient to apply this power to a mixer located in the scum zone of the digester than to a pump located outside, with attendant losses in valves and piping. Also, a properly designed mixer can agitate the entire scum, which is difficult with any practical pumping arrangement.

This does not necessarily mean greater overall power consumption because experience has shown that intense agitation for short periods is probably more effective than prolonged gentle agitation. For example, in Germany before the war, Prüss installed a 40 h.p. mixer in a digester with an area equivalent to about a 40-ft. diameter tank. The mixer was operated about 30 minutes a day and, according to reports by Dr. Fischer, was very successful in keeping down all traces of scum. This may be going to extremes, but it shows what is possible.

Another illustration of the effect of agitation of a less violent type is at Winnipeg, Manitoba, as described in *Water and Sewage,* February, 1946, in an article by Supt. D. L. McLean. At this plant there are four digesters, of which two were originally equipped with stirring devices and two were not. It was found that, because of scum troubles, the two units without scum equipment handled only half the solids that the other two units with scum equipment did. After several years of operation, scum breaking equipment was installed in the plain units. As a result, the net increase in effective digestion capacity was equal to one complete digester. In this plant the covers are not submerged.

Digester Capacity

Another important engineering factor in design which seems to have a bearing upon scum formation, and on operation as well, is the capacity provided in the digesters. Careful study of a large number of plants leads to the conclusion that those plants with a limited digester capacity of less than 25 to 30 days, based on the volume of the raw sludge feed, almost invariably have trouble with scum or supernatant or both. Those plants with digester capacities of 50 or 60 days or longer almost invariably have no serious scum or supernatant problems. In other words, providing a liberal sludge diges-

tion capacity seems to go a long way toward solving scum problems.

Scum Resulting from Sludge Thickening

There is one source of scum trouble in digesters which appears to be a combined design and operating problem. It may result from lack of capacity or from the zeal of the operator. This refers to the prevailing practice of trying to thicken sludge in the digesters. This is an understandable desire in many plants where digested sludge is to be filtered, or where sludge bed capacity is limited.

Any such thickening of the digested sludge, however, usually results in a deterioration of the quality of the supernatant, and when the supernatant is bad, scum troubles can be expected. As a rule, the shorter the digestion period, the greater the tendency to want to thicken, and the more the sludge is held back in the digester for thickening, the more the supernatant and scum are adversely affected. Part of the remedy for this condition is to provide greater capacity in the digester, and part of it is to thicken the sludge in the clarifier or thickener before it is put into the digester. Then, having done this, if the operator also makes certain that he removes, via the sludge outlet, the digested sludge at the rate at which it is accumulating, one major cause of scum formation, and supernatant troubles as well, will be eliminated.

Summary

Summarizing, scum control in digesters is a broader subject than it might appear to an individual operator faced with the problem in his own plant. Scum prevention by removal of scum forming materials from industrial wastes, perferably at the source, is very effective and lasting in benefits.

The operator, depending upon the facilities available in his plant, can obtain relief by applying more heat, by recirculation, by mixing, and by using scum draw-off connections. The designing engineer can design greater digester capacity into the plant and also provide a design which will allow scum formation once formed to be adequately dealt with.

In any plant the final burden is upon the operator. If he makes certain that everything he puts into the digester as raw sludge is ultimately removed as gas, supernatant or digested sludge, his problems are bound to be fewer.

SCUM CONTROL IN DIGESTERS—A DISCUSSION

By Harry E. Schlenz

Vice-President and Sales Manager, Pacific Flush Tank Company, Chicago, Ill.

The paper presented on the subject by Mr. Rankin gives a clear picture of the "scum problem" and includes a complete analysis of the types of scum which may be encountered in digesters.

We are mainly interested in the grouping of scum forming matter into two general classifications, namely: (1) non-digestible accumulations, and (2) digestible accumulations.

Non-digestible accumulations in digesters of a plant receiving a normal domestic sewage represent such a small amount of material that no particular problem is encountered with them. Mr. Rankin has covered quite completely the question of scums from sewages containing a large percentage of non-digestible material due to industrial wastes.

The grouping of scums under "digestible accumulations" represents the major bulk of floating material encountered in the normal digestion

installation, and is the type with which plant operators are mainly concerned in connection with "control measures." Such scum accumulations may be generalized into the following characteristics:

(a) High volatile content, ranging from 70 per cent to 90 per cent volatile solids.

(b) Contain a large percentage of fats and soaps.

(c) May become quite compact and stiff, with as high as 25 per cent solids, if not controlled.

Until recent years, it has been the practice of many plant operators to avoid adding scum or greases, removed from sewage by clarifiers or grease separation tanks, to the digestion system, to attempt to avoid scum accumulations in digesters. Many digesters are equipped with scum draw-off pipes, which are used to remove and dispose of scum accumulations outside of the digestion system.

Actually the digester is the ideal place to dispose of greases and scum, and the emphasis should not be placed on the difficulties encountered with scum accumulations, but rather on the benefits that may be derived from this material as far as gas production and the composition of such resulting gas are concerned.

In any digester where raw solids are added, scum will tend to separate and form at the top of the tank. As long as the scum thus formed does not exceed a foot or two in depth, and is of a soft consistency, there is good indication that it is not accumulating and is undergoing normal digestion. In digestion systems receiving an abnormally high loading of raw solids, or where the grease content of the sewage is high, scum may build up quite rapidly, with such scum accumulations seriously affecting the digestion of the solids in the balance of the tank, by reducing the volume available for active digestion.

Control Procedures

Although as recently as ten years ago the literature gave evidence of the doubt of investigators that greases could be digested within any reasonable length of time; it is now definitely indicated that greases are readily digestible, with resultant higher percentage reduction of the volatile content of the greases than of the balance of the volatile solids in the digestion system. It is therefore evident that if the proper conditions are provided in the scum mass, it is possible to promote the rapid destruction of the fats and soaps present. In the destruction of these materials by digestion, lower fatty acids are first formed, which digest further to produce methane and carbon dioxide.

The extent to which control measures must be employed to promote the destruction of scum accumulations is dependent upon the amount and character of the scum forming matter in the sludge added to the digestion system, and may involve one or more of following procedures.

Liquid Saturation

Scum accumulations should be kept in intimate contact with the liquid contents of the digester, which contain active organisms to promote the desired rapid digestion. This may be accomplished by:

(a) Positive submergence, by an impervious structure of the materials which tend to float, thus preventing the scum from rising into the gas zone where it may become permeated with this end product of digestion and tend to become dry to some extent. Such submergence, which will suffice in preventing the building up of scum accumulations in the majority of digester installations, does not require the expenditure of power, and even where additional control measures are required, the advantages gained through

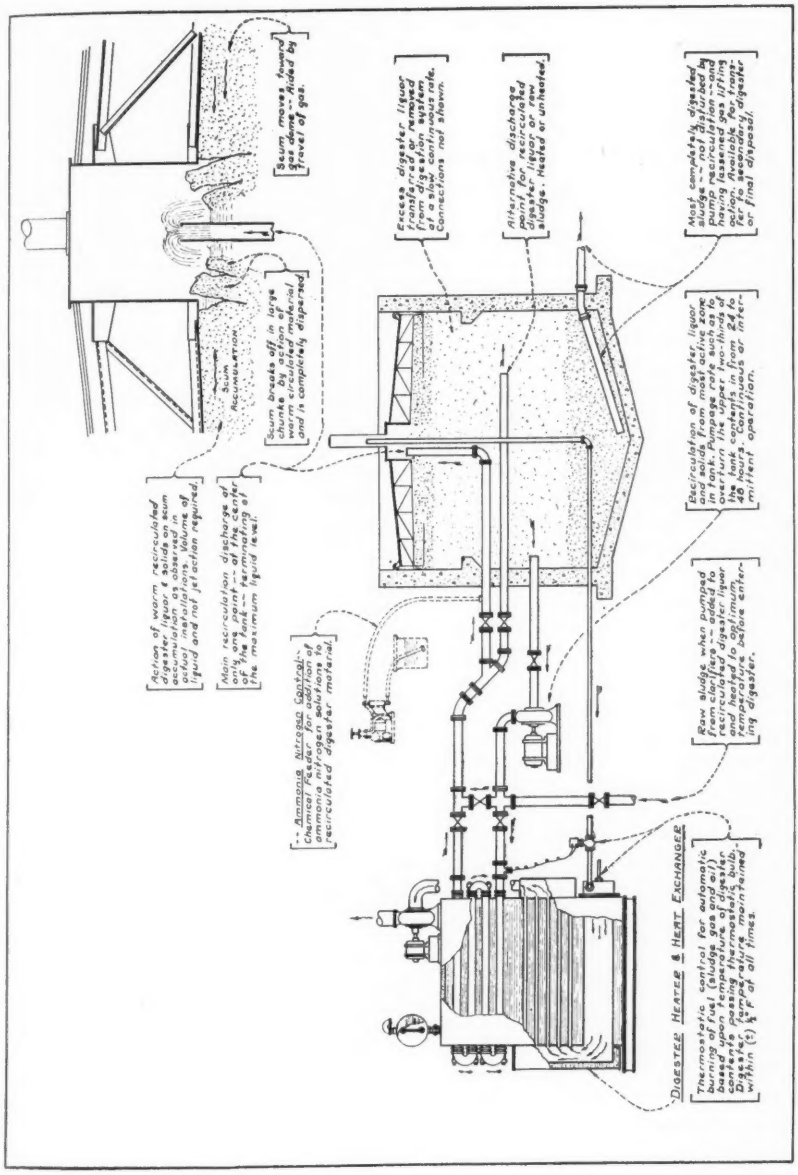
Scum
Accumulation
Scum moves toward gas dome aided by current of gas.
Scum breaks off in large chunks by action of mixing device and is completely dispersed.
Excess digester liquor transferred or removed from digestion system at a specific controlled rate. Connections not shown.
Alternative discharge point for recirculated digester liquor or raw sludge. Heated or unheated.
Most completely digested sludge -- not disturbed by pump recirculation nor mixing action. Available for transfer to secondary digester or final disposal.
Action of warm recirculated digester liquor & solids on scum accumulation is absent in actual installations. Volume of liquid and not jetaction required.
Main recirculation discharge at 3/4 the tank -- terminating at the maximum liquid level.
-- Ammonia Nitrogen Control: Chemical Feeder for addition of ammonia compounds to recirculated digester material.
Recirculation of digester liquor and solids from most active zone in tank. Pumps rate such as to recirculate digester liquor in the tank contents in from 24 to 48 hours. Continuous or intermittent operation.
Raw sludge when pumped from clarifiers added to recirculated digester liquor and heated to optimum temperature before entering digester.
DIGESTER HEATER & HEAT EXCHANGER
Thermostatic control for automatic burning of fuel (sludge gas and/or heating oil) to maintain digester contents passing thermostatic bulb. Digester temperature maintained within (±) ½° F at all times.

FIGURE 1.—Diagram illustrating methods of scum control in digestion tanks.

submergence would indicate the feasibility of its use.

(b) Recirculation of digester liquor from portions of the tank contents where solids are undergoing the most active digestion, with the discharge of the recirculated material into the scum zone, as shown in Figure 1.

In practicing such liquor recirculation, even when confronted with very troublesome scum conditions, it has been demonstrated that it is not necessary nor desirable to discharge the recirculated liquor into the scum with any appreciable force. The rate of discharge should be such as to cause the recirculation of the volume of the upper two-thirds of the digester in from 24 to 48 hours, either by continuous or intermittent operation of a nonclog pump requiring a low power input. The most completely digested sludge in the lower one-third of the tank should not be disturbed, so as to be available for transfer to a secondary digester or removal to a point of final disposal.

While the writer was engaged in the operation of the sewage testing station at the University of Illinois in 1929, a digester of pilot plant size, when operated at a comparatively high loading of raw solids, persisted in the formation of large quantities of scum. Efforts to control such scum accumulations by slow moving paddles or rapidly moving mixers did not meet with any great amount of success. It was found, however, that the stiff scum could be dispersed by a small stream of recirculated liquor with an expenditure of power of but a fraction of that used in the mixing procedures. It was further found to be more effective to discharge the recirculated liquor at the center of the gas take-off dome at the top of the scum layer, rather than at a number of points in the scum zone.

During the war period many digester installations at camps were confronted with scum problems in concentrated form due to the high grease content of the sewages encountered.

Observations made over an extended period of time in connection with scum control in the digesters at one of the two plants of the Great Lakes Naval Training Center were reported in an article on "Controlled Digestion" which appeared in the May, 1944, issue of THIS JOURNAL. Due to improper starting of digestion and before scum control measures were started, each of the two 65-ft. diameter digesters contained about 9 ft. of yellow sickly-looking scum which had become so concentrated that it was impossible to penetrate the mass with a two-by-four. Digester liquor circulated at a rate of 300 g.p.m. caused the following action to take place: The area of the scum mass immediately adjacent to the relatively gentle discharge of the recirculated liquor first became soft and mushy; then large masses of scum resembling a firm fresh cheese gradually moved from the underside of the floating cover towards the gas dome and broke off in large chunks as they became softened. This action continued and after a few days it was evident that the entire scum mass was of a soft mushy consistency, completely permeated with the digester liquor.

In a recent article appearing in the September, 1946, issue of *Water and Sewage Works*, page 369, R. W. Simpson, formerly Sanitary Engineer at Keesler Field, Miss., reports that digester recirculation was effective in dispersing scum accumulations which were an ever present problem, even though the primary digester was equipped with mechanical mixing equipment. He states, "As long as the scum was kept soft, digestion and settling took place. It was necessary to use this (recirculation) method several times, but in each instance the scum thinned out and completely disappeared shortly thereafter."

Control of Temperature of Scum Zone

The writer agrees with the statement that temperatures of 95° F. or more are effective in softening the greases in scum accumulations. However, it is important that this temperature be maintained in the scum forming zone, as well as in the other portions of the tank. A study of the "inventory" records of digesters characterized by excessive scum accumulations reveals that the temperatures in the scum zone may be 10° to 15° lower than the temperatures which are maintained in the balance of the digesting mass.

Liquor recirculation as previously described, in addition to bringing seeding or actively digested solids into the scum accumulations, also tends to provide the desirable optimum temperatures for digestion in the scum zone.

It is possible by the provision of external heating means to raise the temperature of the recirculated digester contents, and thus greatly increase the rate of digestion of the scum by the discharge of the higher temperature liquor at the surface of the scum layer in a manner as shown in Figure 1. With a heating system of this nature provided with sensitive thermostatic controls it is possible to maintain automatically the temperature of the entire digester contents, including the scum zone, within ± 0.5° F., and thus provide optimum conditions favoring the growth of desirable methane producing organisms.

Furthermore, it is desirable to lessen or eliminate entirely the tendency of scum-forming materials to separate from the raw solids as they are added to the digestion system. This may be accomplished by adding the raw solids to the recirculated digester contents, and then heating the mixture so that on entering the digester initially, the sludge is properly seeded and heated to the optimum temperature for digestion and completely dispersed, thereby accelerating the rate of digestion.

Ammonia Nitrogen Control

In a number of digester installations where especially heavy scum accumulations have been encountered, the addition of relatively small amounts of an ammonia nitrogen compound to the liquor recirculated to the scum zone has been effective in causing the scum to digest quite rapidly and to disappear.

Ammonium sulfate has been used as one source of ammonia nitrogen, the commercial product yielding about 25.6 per cent of ammonia nitrogen. This ammonia salt is readily soluble in an equal weight of water and is easily obtained at low cost.

It is added in relatively small doses of 50 to 100 lb. with continuous liquor recirculation between doses. Additions are made until about 30 p.p.m. of equivalent ammonia nitrogen has been added to the volume of the tank being recirculated, normally assumed to represent one-half of the tank contents.

It has been found that if the ammonium sulfate is added at too rapid a rate there is a tendency for the activity in the scum zone to reach such proportions as to resemble a "foaming" condition. The continued addition of the ammonia salt to an excessive concentration of ammonia nitrogen in the digester may also be detrimental to the digestion of the scum solids.

At the large naval installation previously referred to, the raw sewage contained abnormally large quantities of grease, which, when added to the digester, resulted in such a large bulk of scum that digester recirculation alone was not sufficient to keep it dispersed at all times. In the last two periods of operation in the tabulated data as reported in the article on "Controlled Digestion" previously referred to, it was indicated that 10 days of continuous recirculation of liquor into the

scum zone slowed down the rate at which scum tended to accumulate, but within 6 days after the addition of only one 100-lb. dose of ammonium sulfate, representing 7 p.p.m. of ammonia nitrogen added to the tank contents, the scum accumulation was completely dispersed. During the past two years the plant superintendent at that installation has confirmed these observations many times, and reports that he feels that he has a positive method of controlling scum which previously had presented an operating problem of great magnitude. His procedure is to practice more or less continuous liquor recirculation, which keeps scum accumulations at a minimum and the digestion activity at an optimum point as measured by rate of gas production. Whenever the scum accumulations become excessive in his judgment, he adds 100 lb. of ammonia sulfate to the recirculated liquor and the scum is completely dispersed in a matter of a few days. He has found that on the average it is only necessary to resort to the use of this small dose about once each three months, representing a cost of less than $2.00 per dose for the chemical.

The writer will agree that it is difficult to understand why the addition of such a small amount of ammonia nitrogen to a digesting sludge mixture that is normally high in ammonia nitrogen content will show such definite beneficial results, as measured by scum dispersal and increased gas production.

It is possible that the scum zone may be deficient in ammonia nitrogen and under some conditions the liquor recirculated from other portions of the tank will correct this deficiency and cause the scum to digest. In cases where liquor recirculation alone does not result in sufficient increased activity in the scum zone to destroy the scum accumulation, the addition of the small quantities of ammonia sulfate to the recirculated liquor probably provides ammonia nitrogen in a readily usable form for the organisms, resulting in the increased digestion rate in the scum zone.

Patent Considerations

Some of the procedures suggested in this discussion, such as digester liquor recirculation and ammonia nitrogen control, are covered by patents already issued, while certain phases of external heating of circulated digester liquor and raw solids are covered by pending patent applications. It is therefore necessary from a patent standpoint for an operator wishing to use such procedures to obtain rights to do so. In addition, ammonia nitrogen control should be used only under the guidance of engineers of the Pacific Flush Tank Company to avoid difficulties which may result from improper use of the procedure.

PHOSPHATES IN SEWAGE AND SLUDGE TREATMENT. III.—EFFECTS ON SLUDGE DIGESTION *

By Willem Rudolfs and G. W. Stahl

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Phosphorus plays an essential part in the metabolism of all living cells. It is present in sewage and sewage sludge in varying quantities. It is conceivable that the amounts present may affect the groups of bacteria responsible for liquefaction and gasification of digesting sludge. It is also conceivable that the type of phosphorus compound present may play a role in the degree and rate of anaerobic decomposition.

It is well known that rapidly growing tissues (both plant and animal) frequently exhibit the phenomena of high uptake of phosphorus. This high uptake may be related to the high rate of metabolism of such tissues. Cells that are multiplying at a rapid rate show great avidity for phosphorus, but it appears that the phosphorus must be in a form in which it can be absorbed more or less readily. It may be possible that certain types of phosphorus compounds would stimulate, others retard by temporary overstimulation followed by impairment of the activity of the cell, and still others would exert no measurable effect. The quantities of phosphorus compounds present may also play a role.

This attempt to study the effects of phosphorus compounds has been limited to those compounds normally found in sewage sludge and those which may be introduced more frequently by industrial waste discharges.

Settled sewage solids may contain from 0.75 to 3.0 per cent phosphorus as P_2O_5 on a dry solids basis, whereas digested primary sludge may contain from 1.0 to 4.0 per cent. The average results obtained on a number of sludges from different plants were found to be: for primary sludges, 1.61 per cent expressed as P_2O_5, and for settled and digested sludges, 1.73 per cent (1). A series of 24 samples of fresh and digested sludges obtained from the same plant showed in all cases higher percentages of P_2O_5 in the digested sludges. Sludges obtained from chemically treated sewage contain considerably more (2).

The increase of P_2O_5 in sludge from chemically treated sewage is caused by the precipitation of phosphorus compounds by the chemicals added, whereas the apparent increase in phosphorus in the sludge after digestion is undoubtedly due to the destruction of organic matter by biological activities. Since living things require phosphorus and the organic matter undergoes profound changes during digestion, it is probable that during these changes the organic phosphorus compounds pass through several stages before they are "mineralized" and left in the residue. In the course of these changes, it is conceivable that a portion of the phosphorus is produced in gaseous form, evolving from the sludge and mixed with the other gases formed. Careful laboratory experimentation and tests of the evolved gases, however, did not give quantitative indications of phosphine (3). If any gaseous phosphorus is formed during digestion, the quantities normally would be so small that they would not materially affect the percentages of

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J.

phosphorus present in digested sludge, so that a reduction in total organic matter caused by decomposition would show an apparent increase of phosphorus in the sludge.

Small quantities of phosphorus present in sludge are water soluble, a part of the phosphorus is present as extremely finely divided particles, and another part is present in the form of salts which may be relatively inert. The phosphorus compounds present may be divided, in general, into organic and inorganic compounds. To determine the effect which phosphorus compounds may have on digestion, representatives of both groups were selected.

Methods and Materials

Settled fresh solids and ripe sludge were mixed in proportion of about 1:1.2 and also 1:4 on a volatile matter basis. The total solids of the ripe sludge and fresh solids were varied in different series in an effort to determine the possible effect of solids concentration within certain limits, while the volatile matter ratio between ripe sludge and fresh solids was widened in an effort to increase as well as decrease the effect of phosphorus compounds. The sources of phosphorus additions included calcium monophosphate $Ca(H_2PO_4)_2 \cdot H_2O$, ammonium phosphate $NH_4H_2PO_4$, sodium metaphosphate $NaPO_3$, trisodium phosphate $Na_3PO_4 \cdot 12H_2O$, sodium hypophosphate $NaH_2PO_2 \cdot H_2O$, casein, egg albumen, and calves' brains. The phosphorus compounds were dissolved in small quantities of water before addition to the mixtures or were well suspended directly into the mixtures by thorough shaking. The calves' brains were ground with sewage and added to the mixtures. Analyses were made at the beginning and during the course of digestion and included solids, ash, and pH, while measurements were made of the gas volumes produced. The gases were analyzed for various constituents.

Results

The effect of several phosphorus compounds on volatile matter reduction is indicated in Table 1. The quantity of compound added was in all cases the same, but the phosphorus present in the compounds varied. The actual phosphorus content in the salts added varied from 700 to 1,520 mg. per liter of sludge mixture or from about 0.14 to 0.30 per cent on a dry solids basis. The quantities of phosphorus added in the form of salts, expressed as P_2O_5, were therefore roughly from 20 to 40 per cent of the phosphorus present in the mixtures. The amount of phosphorus added in the form of organic compounds was much less. The sludges employed for this particular experiment contained:

	Total Solids (%)	Ash (%)
Ripe sludge	5.46	2.29
Fresh solids	3.31	0.67

with a volatile matter ratio of about 1.2:1 in the ripe sludge and fresh solids, respectively.

The effect of casein was somewhat depressing, but there was little or no effect from the addition of about 1 per cent albumen. The addition of calves' brains resulted in violent foaming, in-

TABLE 1.—Effect of Added Phosphorus Compounds on Volatile Matter Reduction (Sludge Ratio 1 : 1.2)

Chemical Added	Phosphorus Added (p.p.m.)	Initial Total Solids (%)	Initial Ash (%)	Solids Reduction (%)	Vol. Matter Reduction (%)
$Ca(H_2PO_4)_2 \cdot H_2O$	700	4.84	38.4	29.4	39.6
$NH_4H_2PO_4$	1,390	4.86	30.4	30.0	49.9
$NaPO_3$	1,520	4.88	40.8	28.6	41.8
$NaH_2PO_2 \cdot H_2O$	1,500	4.80	37.9	17.7	30.6
Na_3PO_4	1,050	4.67	36.0	30.8	49.2
Casein	43	4.65	30.9	30.3	42.9
Albumen	—	4.89	30.3	33.9	50.0
None	0	4.38	33.8	33.1	48.0

tensive odors, and generally unsatisfactory digestion. For these reasons the results obtained have not been included in the tables.

The effect of the various salts was not uniform. Sodium hypophosphate, calcium monophosphate and sodium metaphosphate showed pronounced retardation in volatile matter reduction, whereas ammonium phosphate and trisodium phosphate showed no effect. As was to be expected, none of these compounds exerted a material effect on the pH values during digestion. The percentage of volatile matter reduction in the mixture without phosphorus addition indicates that digestion was virtually completed. A decrease in the percentage of volatile matter reduction would indicate that liquefaction was retarded or partly inhibited.

Since the effect of the various phosphorus compounds is not constant, it appears that the type of phosphorus compound may affect liquefaction. It is also possible that the quantity of phosphorus compound may be a factor. In no case was stimulation of liquefaction evident in this series of experiments. It is conceivable, however, that increasing quantities of phosphorus compound may cause greater retardation or entirely inhibit activities, or that decreased amounts of the same phosphorus compound may actually stimulate the biological activities.

The fact that phosphorus is necessary to maintain biological activities at a high rate would tend to indicate that certain phosphorus compounds may stimulate liquefaction if insufficient phosphorus is present for maximum activities. An example of the mildly stimulating effect is afforded by the results obtained when increasing quantities of ammonium phosphate were added to fresh solids-ripe sludge mixtures (Table 2). With larger additions of ammonium phosphate, the percentage volatile matter reduction increased. The fact that a small amount of phosphate did not stimulate liquefaction,

TABLE 2.—Effect of Phosphorus ($NH_4H_2PO_4$) Concentration

Phosphorus Addition (p.p.m.)	Initial Total Solids (%)	Initial Ash (%)	Vol. Matter Destroyed (gr./l.)	Vol. Matter Reduction (%)
2,780	5.35	26.0	21.0	52.8
1,390	4.86	30.4	16.8	49.9
695	4.63	32.0	13.8	43.8
0	4.38	33.8	13.9	43.0

but that doubling the quantity had some effect, whereas trebling the dose did not further stimulate liquefaction, would seem to indicate that an optimum quantity of phosphorus is required to exert an effect.

The quantities of organic phosphorus added to the mixtures were relatively small and seemed to have little effect. Any effect noticed was probably due to the organic matter added rather than to the phosphorus.

Ripe sludge contains a materially higher P_2O_5 content than fresh solids. If any stimulating or retarding effect is caused solely by the quantity of phosphorus present, and is not related to the type of phosphorus compound, it would be expected that increasing the amount of ripe sludge in relation to fresh solids (i.e. increasing the total phosphorus present) should have practically no effect on the rate of digestion. It is well known, however, that increasing the quantities of ripe sludge in the mixtures leads to more rapid and more complete digestion of the volatile matter in the fresh solids added. Moreover, the addition of larger amounts of seed material reduces the possibility of experimental errors. Accordingly, a series of mixtures were prepared, producing volatile matter ratios of 1:4 on a dry fresh solids-ripe sludge basis.

On the assumption that only the volatile matter in the fresh solids was decomposed, the percentages of reduction were calculated on this basis. This assumption is obviously not entirely correct, but allows a better comparison

TABLE 3.—Effect of Phosphorus on Volatile Matter Reductions in Mixtures with Wider Fresh Solids—Ripe Sludge Ratios (1 : 4)

Chemical	Chemical Added (gm./l. mxt.)	Phosphorus Added (mg./l. mxt.)	Initial Total Solids (%)	Initial Ash (%)	Vol. Matter Reduction in Fresh Solids (%)
$Ca(H_2PO_4)_2 \cdot H_2O$	5	700	7.72	50.1	48.8
$NH_4H_2PO_4$	10	2,780	8.32	42.1	101.2
$NH_4H_2PO_4$	5	1,390	7.80	44.6	80.8
$NH_4H_2PO_4$	2.5	695	7.60	45.8	75.6
$NaPO_3$	10	3,040	8.33	54.0	42.8
$NaPO_3$	5	1,520	7.85	51.1	55.2
$Na_3PO_4 \cdot 12H_2O$	5	400	7.89	50.1	81.2
$NaH_2PO_2 \cdot H_2O$	5	1,470	7.74	49.5	53.6
Casein	5	43	7.84	44.6	75.6
None	0	0	7.32	47.7	75.2

of the effect of the various phosphorus compounds.

The condensed results (Table 3) show that relatively small quantities of phosphorus in the form of casein, trisodium phosphate, and ammonium phosphate exerted little or no effect on liquefaction. The percentage volatile matter reduction was materially depressed by sodium hypophosphite, trisodium phosphate, and calcium monophosphate. The retarding effects were particularly noticeable during the early stages of digestion. It appears, therefore, that the type of phosphorus compound is of importance.

Increasing the quantities of ripe sludge, and thereby supplying larger amounts of phosphorus, apparently did not decrease the beneficial effects of increasing quantities of ammonium phosphate. There is, however, a question whether the stimulating effect of this compound was due to the phosphorus or was the result of increasing amounts of ammonia.

Results of another series with a higher solids concentration and a somewhat wider volatile matter ratio of 1 part fresh solids to 4.5 parts ripe sludge on a dry basis again showed marked retardation of volatile matter reduction by the addition of calcium monophosphate, trisodium phosphate, and sodium hypophosphite (Table 4). Increasing the quantities of calcium monophosphate or trisodium phosphate did not materially decrease the percentage volatile matter reduction as compared with the smaller quantities added.

The effect of several of the phosphate compounds on total gas production and the amounts of combustible gas produced per gram volatile matter destroyed are given in the same table.

In all cases where phosphate compounds were added, the quantity of total gas produced per gram volatile matter in the fresh solids added was less than that produced in the control mixture. In spite of the fact that ammonium phosphate may aid in liquefaction, the total amount of gas produced

TABLE 4.—Effect of Phosphorus Compounds on Volatile Matter Reduction and Gas Production (Sludge Ratio 1 : 4.5)

Chemical	Chemical Added (gm./l. mxt.)	Phosphorus Added to Mixtures (p.p.m.)	Initial Solids (%)	Initial Ash (%)	Vol. Matter Reduction in Fresh Solids (%)	Gas per Gram Volatile Matter in Fresh Solids (ml.)	Combustible Gas per Gram Vol. Mat. Red. (ml.)
$Ca(H_2PO_4)_2 \cdot H_2O$	10	1,400	9.95	50.6	40.0	360	900
$Ca(H_2PO_4)_2 \cdot H_2O$	5	700	9.51	50.9	40.7	372	860
$Ca(H_2PO_4)_2 \cdot H_2O$	2.5	350	9.30	50.0	41.4	391	830
$NH_4H_2PO_4$	5	1,390	9.54	45.4	63.8	357	600
$NH_4H_2PO_4$	2.5	695	9.30	47.8	56.9	384	560
$NaPO_3$	10	3,040	10.10	53.0	45.4	390	710
$NaPO_3$	5	1,520	9.61	51.4	52.6	498	670
$Na_3PO_4 \cdot 12H_2O$	5	1,050	9.53	51.2	40.5	312	690
$Na_3PO_4 \cdot 12H_2O$	2.5	525	9.30	50.2	41.4	328	860
None	0	0	9.05	48.7	59.6	500	640

was from 25 to 30 per cent less than the gas obtained from the control. The amount of combustible gas produced was, however, only slightly less than that of the control. This indicates that the composition of the gas as well, as the quantity, may be affected by the phosphate compounds. Of interest in this respect is that the amounts of combustible gas produced from a unit quantity of volatile matter destroyed in the fresh solids in all cases (except ammonium phosphate) were higher than in the control.

Total gas production was rather uniformly retarded by the addition of phosphorus compounds. This is shown by the curves in Figure 1, where the amounts of combustible gases produced from the various mixtures are compared. The picture is somewhat different when the gas production per unit volatile matter destroyed is plotted (Figure 2). Calcium monophosphate and sodium metaphosphate appeared to produce more combustible gas per unit of volatile matter destroyed, although the total quantity of volatile matter reduced was materially less than that of the controls. Trisodium phosphate caused retardation in combustible gas production per unit of volatile matter destroyed, but eventually the retardation seemed to be overcome.

In general, all phosphorus compounds added retarded the rate of gas formation, increased the time for digestion as compared with mixtures receiving no phosphates, and produced less combustible gas from equal amounts of volatile matter in the fresh solids.

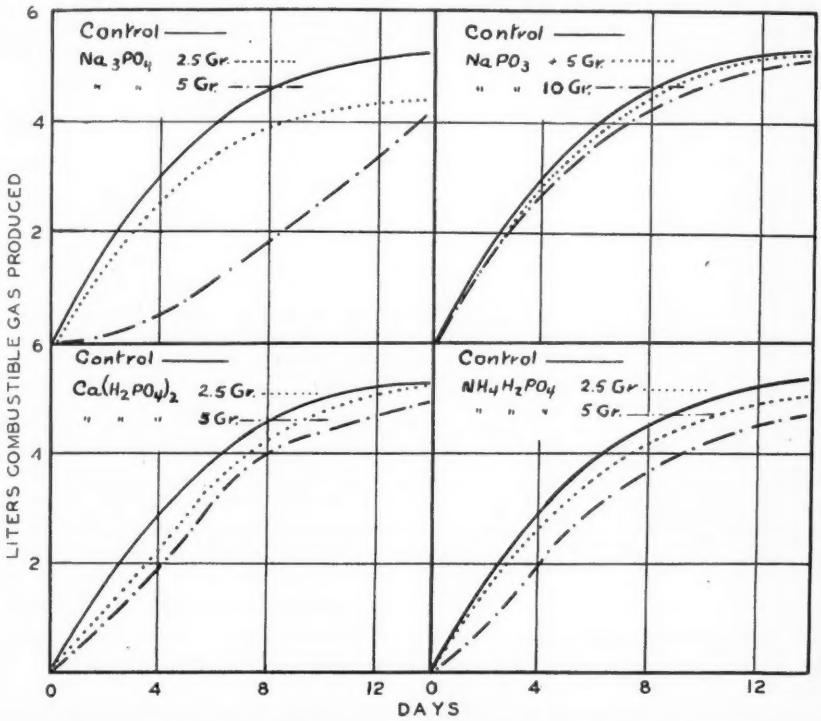

FIGURE 1.—Effect of various types of phosphorus compounds on the rate of gas production.

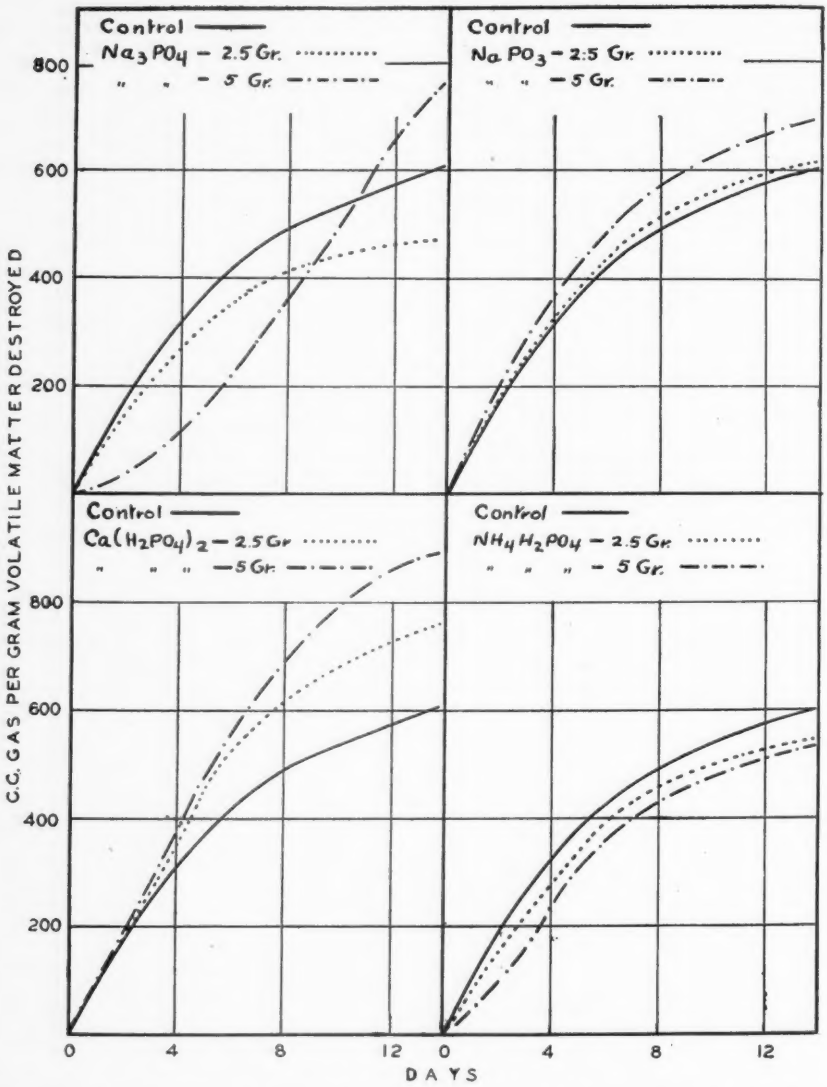

FIGURE 2.—Effect of various phosphorus compounds on the gas production per unit of volatile matter destroyed during digestion.

Discussion

In an effort to determine the effect of phosphorus compounds on liquefaction and gasification of digesting sludge mixtures, no direct correlations were found between the quantity of phosphorus present and the rate of decomposition. Although all phosphorus compounds tried retarded the rate of gasification, the depressing effect does not seem to be the result of the phosphorus as such, but rather to be caused by the particular compound under consideration.

A correlation between the amount of phosphorus and the retarding or stimulating effects would be comparatively simple if the toxic or stimulating nature of the materials affected the liquefying flora in the same way as the organisms responsible for gasification. It appears, however, that certain types of phosphorus compounds added in relatively high concentrations may stimulate volatile matter reduction, with smaller quantities having no appreciable effect, whereas other types of phosphorus compounds may have a marked depressing effect on liquefaction.

Although in all cases the phosphorus compounds appeared to have a retarding effect on the rate and total quantities of combustible gas production, the amounts of combustible gases produced per unit of volatile matter destroyed varied and were usually higher than the amounts of combustible gases produced from volatile matter to which no phosphorus compounds had been added. This may indicate that the decomposition of specific substances present in the fresh solids was affected by the phosphorus compounds. Since a considerable portion of the combustible gases originates from fats and greases from which the gas producing organisms could not obtain the necessary phosphorus for their metabolic processes, it is conceivable that grease destruction was relatively higher in the mixtures to which phosphorus compounds were added than in the mixtures not receiving phosphorus. As no grease determinations were made at the time, however, this question remains to be investigated.

The retardation of total gas production by the addition of phosphorus compounds is similar to results obtained in previous work (4) when various types of sulfates were used. In the previous studies, it was found that the retarding effect increased with a decrease in the alkaline character of the salt added, but this cannot be applied to the addition of phosphorus compounds.

While calcium monophosphate exhibited a greater retarding action on volatile matter reduction, and about an equal effect on gas production than ammonium phosphate, trisodium phosphate also exhibited a pronounced retarding effect on volatile matter reduction and an even greater retarding effect on gas production, despite its alkaline nature. While sodium metaphosphate did not markedly alter the pH value of the digesting mixture, its addition resulted, nevertheless, in a decreased volatile matter reduction and a slowing up of the rate of combustible gas production.

A comparison of the results obtained from the lower solids concentration with those from the higher solids concentration to which the same amount of phosphorus compounds were added to equal volumes of sludge, but which in effect received nearly double the phosphorus compounds per given unit of volatile matter in the fresh solids, indicates that the amount of phosphorus compounds added exerts an influence only up to a certain concentration. The same effect is noted when increasing qantities of the same phosphorus compounds are added to about equal solids concentrations. This again may possibly indicate that the decomposition and gasification of specific compounds present in a limited amount in the sludge mixture may be affected. Whether this effect is the result of phosphate precipitation and locking up of volatile substances, or retardation of biological activities through toxicity of the compounds, is a question which cannot be answered definitely with the information available.

Summary

For the purpose of determining the effect of phosphorus on the liquefaction and gasification of digesting sludges under mesophillic conditions, different

phosphorus compounds were added in various concentrations to mixtures of fresh solids and ripe sludge. In different series the solids concentrations in the mixtures were varied from 4.5 to 9.0 per cent, whereas the dry volatile matter ratios of the fresh solids and ripe sludges were varied from 1:12 to 1:4.5.

Volatile matter reduction was generally decreased by additions of phosphorus compounds, with the exception of some phosphate concentrations, indicating that the liquefying organisms were not in need of additional phosphorus for their metabolic processes.

Total combustible gas production per unit of volatile matter was decreased in all cases, and the rate of gas production was retarded. However, the amounts of combustible gas produced per unit of volatile matter destroyed were increased by the addition of phosphorus compounds, possibly indicating that the destruction of certain substances in the sludge was enhanced. The fact that the amount of combustible gas produced per unit of volatile matter destroyed was greater with the addition of phosphorus compounds would also lead to the assumption that the decomposition and gasification of specific substances in the sludge was retarded or inhibited.

If phosphorus compounds present in certain industrial wastes amount to 25 per cent or more of the phosphorus naturally present in domestic sewage sludge, some retardation in activities may be expected, resulting in more time required for digestion or in increased digestion capacities.

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STUDIES OF SEWAGE PURIFICATION. XVII.—THE UTILIZATION OF ORGANIC SUBSTRATES BY ACTIVATED SLUDGE *

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These studies on sewage purification were started over ten years ago with a paper on the development of an apparatus for determining dissolved oxygen in activated sludge. Sixteen papers in the series had been completed to the beginning of world hostilities in December, 1941. From the titles of these papers, as given below, it will be noted that the studies have been directed largely toward increasing our knowledge and understanding of the fundamental physical, chemical, and biological mechanisms of the secondary processes of sewage purification with the object of the application of the knowledge to the practical problems of plant design and operation.

Preceding papers in the series are:

Theriault, E. J. and McNamee, P. D., "Studies on Sewage Purification. I.—Apparatus for the Determination of Dissolved Oxygen in Sludge-sewage Mixtures." *Pub. Health Rep.*, **50**, 480 (1935). Reprint 1680.

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* Presented at the 18th Annual Meeting, Central States Sewage Works Association, Lafayette, Ind., June 13–14, 1946.

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Moore, W. Allan, Ruchhoft, C. C. and Wattie, Elsie, "Oxidation Reduction Studies. I.—Oxidation Reduction Potentials Developed by Pure Cultures in Sewage." THIS JOURNAL, **14**, 980 (1942).

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Papers XI and XII were concerned with a study of the mechanism of the rapid removal and ultimate disposal of the non-electrolyte solutes which occur in sewage. In the above two papers, glucose was used as an example of this type of compound and the mechanism of its removal and utilization by activated sludge was intensively studied. This study was then extended to include various other organic solutes and was well under way when interrupted by the war. Transfer of personnel and other activities prevented the continuation of the study. Now the data which were accumulated over a period of years and embrace a wide range of compounds, including sugars, alcohols, aldehydes, organic acids, amino acids and certain miscellaneous compounds, have finally been gathered together and summarized.

The data presented are particularly informative in the case of carbohydrates, as they confirm conclusions previously drawn from glucose studies. They illustrate to some extent the great versatility of activated sludge through its ability to attack and utilize a wide variety of quite dissimilar materials. In view of the fact that activated sludge is commonly considered in relation to its utilization and stabilization of normal wastes, these data are remarkable, not so much for the materials not oxidized and not usable as a source of energy, but for the large number of chemically unlike materials utilized. Some interesting accessory phenomena such as adaptability with carbohydrates and growth of *Sphaerotilus natans* are included.

These data are not to be construed as an attempt to discover the optimum conditions for the utilization of each material used. They should, instead, be interpreted as the response of activated sludge to each material under more or less average and standardized conditions.

Procedure

The oxidation studies were carried out using an aeration device previously described (1). Essentially it is a closed system aeration chamber actuated by a mercury pump and containing a known volume of air. The initial oxygen content may be determined as well as subsequent changes at appropriate intervals by withdrawing small samples of air for analysis. Aeration with each substance was continued for 22 to 24 hours, and samples taken at 1, 3, 5 and 22- to 24-hour periods. A constant temperature of 20° C. was maintained throughout the oxidation period.

A basic mineral buffer solution (1) was used throughout the entire series of experiments. This was presumed to contain the same mineral materials in about the same concentrations as are normally found in sewage. The following ions were contained in this solution: ammonium, sodium, potassium, calcium, magnesium, phosphate, sulfate and chloride. The urea and pep-

tone mentioned in the reference were omitted for these studies. An equivalent quantity of this solution was used to replace the supernatant withdrawn from one liter of activated sludge. It was thought advisable to keep the concentration of activated sludge solids at about 2,000 p.p.m. but at times there were variations from this ideal. In these experiments, the test material to be used as the sole source of energy or carbon was added to the prepared activated mixture and the increment of oxygen utilized by this addition was determined. In all cases, an identical control sludge minus the test material was similarly run. A record of pH was kept, and in most cases the sludge index was determined. The biochemical oxygen demand of the test material was determined at 2-day intervals through 10 days. In certain instances pure culture zooglea sludges with much lower solids content were used.

Carbohydrates

Seven carbohydrates were studied. This included l-xylose, glucose, maltose, lactose, sucrose, dextrin and soluble starch. The carbohydrate data obtained are interesting, confirming previously published data on the mechanism of glucose removal from solution by activated sludge (2, 3) and extending those conclusions to a greater variety of carbohydrates, some of which are more complex in molecular structure.

In Table 1 are data concerning the nature of the carbohydrates used and the theoretical oxygen demands to be anticipated. Table 2 gives solids and biochemical oxygen demand data, and Table 3 lists the experimental oxidation figures and results obtained when individual carbohydrates are used alone as a substrate feed with sludge.

It would seem that size, chemical structure and solubility of the carbohydrate molecules are all important factors in their rate of removal from the supernatant liquor by activated sludge. Different sludges would, however, probably exert some influence, that is the initial capacity to utilize carbohydrates might be greater in some than in others.

There is an adsorption of carbohydrate immediately after mixing with sludge solids. The percentage, evident in all cases, varied with the carbohydrate. It amounts to 4 to 7 per cent for l-xylose, glucose and lactose, 13 to 15 per cent for sucrose and maltose and 30 to 80 per cent for dextrin and

TABLE 1.—Basic Data on Carbohydrates Studied

Carbohydrates	Class	Formula	Molecular Weight	Equivalent Wt. of Oxygen for Oxidation	Theoretical B.O.D. per Mg. per Liter† (p.p.m.)	
					Ultimate	5-day
l-Xylose	Pentose	$C_5H_{10}O_5$	150.13	160	1.07	0.73
d-Glucose	Hexose	$C_6H_{12}O_6$	180.15	192	1.07	0.73
Maltose	Disaccharide-reducing	$C_{12}H_{22}O_{11}+H_2O$	360.31	384	1.07	0.73
Lactose	Disaccharide-reducing	$C_{12}H_{22}O_{11}+H_2O$	360.31	384	1.07	0.73
Sucrose*	Disaccharide non-reducing	$C_{12}H_{22}O_{11}$	342.29	384	1.12	0.77
Dextrin	Polysaccharide	$(C_6H_{10}O_5)x$	162.14	192	1.18	0.81
Starch	Polysaccharide	$(C_6H_{10}O_5)x$	162.14	192	1.18	0.81

* Common sugar.

† On the assumption that the substrate contains enough nitrogen for the metabolic needs of the microorganisms to permit complete oxidation.

TABLE 2.—B.O.D. Removal Data on Activated Sludge Fed with Carbohydrates (Aeration time in all experiments was 22 to 24 hours)

Carbohydrate Fed	Initial Conc. of Carbohydrate Fed in Sludge Liquor (p.p.m.)	Sludge Index	pH		Suspended Solids (p.p.m.)			5-day B.O.D. of Supernatants (p.p.m.)			Percentage of Theoretical Initial 5-day B.O.D. Removed in 22–24 Hrs.	Percentage of B.O.D. Observed After Mixing Removed in 22–24 Hrs.
			Initial	Final	Initial	Final	Indicated Change	Theoretical Initial	Observed Immediately After Mixing	Observed After 22–24 Hrs.		
l-Xylose	500	37.5	6.7	5.7	1,984	1,960	− 24	365	340	140.0	61.6	58.8
l-Xylose	500	37.5	6.7	5.7	1,972	1,984	+ 12	365	315	155.0	57.5	50.8
d-Glucose*	699	—	—	—	2,011	—	—	510	486	1.5	99.7	99.6
	979	—	—	—	1,884	—	—	715	672	3.0	99.7	99.6
Maltose	667	41.7	6.8	5.9	2,088	2,356	+268	487	320	4.1	99.1	98.7
	667	41.7	6.9	5.8	2,104	2,348	+244	487	310	7.1	98.5	97.7
Lactose	500	—	6.6	6.1	3,176	3,592	+416	365	249	4.2	98.8	98.4
Sucrose	500	—	6.4	6.6	3,024	3,284	+260	385	332	4.5	98.8	98.6
Dextrin	667	54	7.0	6.7	2,292	2,400	+108	540	126	51.0	90.6	60.3
	667	54	7.0	6.5	2,372	2,412	+ 40	540	117	21.0	96.1	32.1
	500	—	6.5	6.4	2,936	3,504	+568	405	288	5.8	98.6	98.0
Starch	500	36.3	6.5	6.7	2,492	2,380	−112	405	98	9.5	97.6	90.3
	500	36.3	6.5	6.5	2,528	2,412	−116	405	75	8.2	98.0	89.1
	500	—	6.6	5.6	3,596	3,772	+176	405	224	5.0	98.8	97.1

* From paper XII, this series, Table 1, page 583.

TABLE 3.—Oxidation of Carbohydrates by Activated Sludge †

Carbohydrates Fed	Quantity of Carbohydrates Fed (p.p.m.)	Quantity of Sludge Used in Experiment (p.p.m.)	Mg. of O_2 Used in 24 Hrs. by Control Sludge	Mg. of O_2 Used in Indicated Time (hours) as a Result of Carbohydrate Feed				Per Cent of Theoretical Ultimate Carbohydrate Demand Satisfied in Indicated Time (hrs.)			
				1	3	5	22 to 24	1	3	5	22 to 24
l-Xylose	500	1,984	132.3	0	0	0	52.3	0	0	0	9.78
	500	1,972	132.3	0	1.6	2.6	37.5	0	0.30	0.49	7.50
Glucose*	1,000	—	139.9	34.3	60.2	75.0	107.8	3.21	5.63	7.01	10.1
	720	3,228	246.7	27.0	48.1	59.1	—	3.50	6.24	7.67	—
Maltose	684	2,784	141.4	8.6	5.0	6.6	0	1.17	0.68	0.90	0
	684	3,272	176.2	27.9	56.8	71.5	163.8	3.81	7.76	9.77	22.4
	667	2,088	113.2	9.0	42.5	58.4	61.5	1.26	5.94	8.18	8.61
	667	2,104	113.2	7.3	26.7	41.5	45.2	1.02	3.74	5.81	6.33
Lactose	684	3,228	246.7	25.0	51.9	90.6	157.9	3.41	7.09	12.4	21.6
	684	3,028	154.4	24.6	59.4	77.5	175.1	3.36	8.11	18.6	23.9
Sucrose	684	2,784	141.4	16.6	49.3	70.0	54.1	2.17	6.44	9.14	7.11
Dextrin	667	2,292	184.5	0	13.8	10.2	0	0	1.75	1.30	0
	667	2,372	184.5	16.8	37.7	33.2	38.8	2.13	4.79	4.22	4.92
Starch	500	2,492	86.2	0	0	0	0	0	0	0	0
	500	2,528	86.2	0	0	0	0	0	0	0	0

* From Paper XII, this series, Table 1, page 583.
† Normal activated sludge (*i.e.* plant sludge).

starch. After this initial adsorption there is a continuous removal of dissolved material from solution. Referring to Table 2, it is at once apparent that during a 22- to 24-hour aeration period better than 90 per cent of the B.O.D. of all carbohydrates used, with the exception of l-xylose, was removed from solution. Fifty to 60 per cent of the l-xylose was removed. That even this low percentage may be increased under certain conditions may be seen by referring to Table 4.

It has been previously demonstrated with respect to glucose (2) that repeated feedings of that material produce a sludge capable of removing glucose at much higher rates than the unacclimated sludge. Table 4 demonstrates that this property of activated sludge can be applied to l-xylose to increase its utilization and can also be extended to starch and dextrin to increase their rate of removal. With respect to the pentose sugar, l-xylose, not only is the rate of removal more rapid over a 22- to 24-hour aeration period but the over-all removal is increased to about 98 per cent. This is especially significant in view of the rather poor B.O.D. removal in a similar period by an unacclimated sludge. Starch exhibits a similar increased rate of removal. The over-all removal for dextrin is also much more rapid, using the acclimated sludge; the 5-hour rate approaching the 22- to 24-hour rate in the case of the unacclimated sludge.

In acclimating the activated sludges used in Table 4, the solids were considerably increased and some of the data presented in the table were obtained by using acclimated sludges higher in suspended solids than the controls. That this does not alter the general trend or significance of the conclusions reached is attested by the second starch experiment run initially and at 22 hours. The acclimated sludge used here is the same one used in the first starch experiment, but with the solids reduced to approximately the same as

TABLE 4.—Comparison of Sludges Acclimated to Various Carbohydrates with Unacclimated Sludges

		Acclimated Sludges					Control Sludges				
	Interval (hrs.)	pH	Suspended Solids (p.p.m.)	Ash (%)	5-day B.O.D. (p.p.m.)	Per Cent Reduction	pH	Suspended Solids (p.p.m.)	Ash (%)	5-day B.O.D. (p.p.m.)	Per Cent Reduction
Xylose	0	7.5	2,940	15.0	610	—	7.3	1,468	24.2	726	—
	1	—	3,016	15.1	464	23.9	—	1,516	22.7	673	7.27
	3	—	3,316	13.5	210	65.6	—	1,524	25.4	572	21.21
	5	—	3,312	13.3	42	93.1	—	1,524	19.4	598	17.63
	23	7.4	3,212	14.2	8	98.7	5.4	1,616	16.1	439	39.53
Dextrin	0	7.7	2,236	10.55	1,118	—	7.5	1,580	22.1	1,350	—
	1	—	2,700	8.00	582	47.94	—	1,696	20.0	1,276	5.48
	2	—	2,856	7.98	386	65.47	—	1,812	19.2	1,002	25.80
	3	—	3,260	8.48	264	76.39	—	1,872	17.95	878	34.97
	5	—	3,192	8.47	106	90.52	—	1,968	16.65	644	52.30
	23	7.3	3,132	6.90	4	99.64	7.1	2,616	13.46	26.9	98.01
Starch	0	7.5	5,532	8.97	1,506	—	7.4	1,616	21.0	1,540	—
	1	—	6,140	7.88	1,048	30.41	—	1,836	18.2	1,430	7.14
	3	—	6,720	7.19	542	64.01	—	1,920	17.3	1,266	17.80
	5	—	7,124	6.90	140	90.70	—	2,108	15.75	1,156	24.99
	23	7.5	6,992	7.21	16.9	98.88	7.3	2,768	12.15	204.5	86.72
Starch	0	7.5	1,852	6.5	1,462	—	7.3	1,740	20.0	1,466	—
	22	7.3	3,244	5.8	16	98.91	7.1	2,880	14.45	213	85.60

those found in a new control sludge. It will be seen that solids increase and per cent B.O.D. removal is very similar to the preceding experiment.

The oxidation experiments (Table 3) emphasize that but a small portion of the material that was absorbed and utilized was completely oxidized. This is true for all carbohydrates studies. In a previous paper (3) it has been shown that only about 11 to 31 per cent of the glucose that is removed from solution is completely oxidized in 22 to 24 hours. From the data presented in Table 3 there is no evidence that any of the starch removed from solution in the first 24-hour aeration period was oxidized. In the case of dextrin about 5 per cent of the material removed could be accounted for by the additional oxygen used in one experiment, but the second experiment indicates an even poorer performance. The remaining carbohydrates, l-xylose, maltose, lactose and sucrose, were oxidized during a 22- to 24-hour aeration period in varying degrees ranging from 7 to 24 per cent.

These values are of similar magnitude to those previously obtained for glucose. It is very apparent that all of these soluble carbohydrates, which are so rapidly removed from solution by activated sludge, are not oxidized to as great an extent as the peptones, and that they are utilized and retained as protoplasm in the zoogleal and other cells.

These interesting facts led to a more complete study of the removal of the complex carbohydrate dextrin from solution. The data obtained are tabulated in Tables 5(a) and 5(b). Biochemical oxygen demand removal rates, solids increases and partition characteristics were determined using a normal activated sludge and also one which had been acclimated to dextrin by previous feedings over a period of several days. The partition characteristics was determined by incubating the several portions with diastase and titrating the reducing sugars formed with ceric sulfate (4).

From the data obtained it is possible to determine an approximate correlation between the biochemical oxygen demand and the amount of reducing material present and also to subdivide the reducing material into those portions present in the supernatant, sludge and that increment not detectable as dextrin or its degradation products. This latter portion represents the portion removed and wholly utilized, probably retained as protoplasm in the

TABLE 5(a).—Characteristics of Dextrin-Acclimated and Unacclimated Sludges (B.O.D. and Solids Data)

Time Interval	Suspended Solids (p.p.m.)		Suspended Solids Increase (p.p.m.)		Suspended Solids Increase (%)		5-Day B.O.D. of Supernatant (p.p.m.)		B.O.D. Utilized (%)	
	A.	U.	A.	U.	A.	U.	A.	U.	A.	U.
Before Feeding	2,072	1,552	—	—	—	—	5.2	4.8	—	—
After Feeding	2,236	1,580	164	28	7.9	1.8	1,118	1,350	23.2	7.3
1-hour...	2,700	1,696	628	144	30.3	9.3	582	1,276	60.0	12.5
2-hour...	2,856	1,812	784	260	37.9	16.7	386	1,002	73.7	31.2
3-hour...	3,260	1,872	1,188	320	57.3	20.6	264	878	82.0	39.7
5-hour...	3,192	1,968	1,120	416	54.1	26.8	106	644	93.0	55.7
23-hour...	3,132	2,416	1,060	864	51.2	55.7	—	—	—	—

5-day B.O.D. of dextrin feed added = 1,457 p.p.m.
A = acclimated.
U = unacclimated.

TABLE 5(b).—Characteristics of Dextrin-Acclimated and Unacclimated Sludges (Reducing Materials Data)

Time Interval	Reducing Carbohydrates in Supernatant				Reducing Carbohydrates in Sludge				Per Cent of Dextrin Not Detectable as Reducing Material	
	Quantity (p.p.m.)		Quantity (%)		Quantity (p.p.m.)		Quantity (%)			
	A.	U.	A.	U.	A.	U.	A.	U.	A.	U.
Before Feeding	20	62	—	—	178	138	—	—	—	—
After Feeding	2,535	2,825	84.0	93.5	470	415	16.0	14.4	0.0	−7.5
1-hour...	1,137	2,303	37.6	76.0	702	387	23.2	12.5	39.2	11.5
2-hour...	378	1,683	12.5	55.8	473	239	15.7	7.9	71.8	36.3
3-hour...	53	1,388	1.8	46.0	418	222	13.9	7.4	84.3	46.6
5-hour...	14	1,020	0.5	33.8	376	236	12.0	7.8	87.5	58.4
23-hour...	70	103	2.3	3.4	219	232	7.2	7.7	90.5	88.9

Reducing material value of added dextrin feed = 3,020 p.p.m.
A = Acclimated.
U = Unacclimated.

zoogleal or other cells, and contributing together with the fraction found as reducing material in the sludge to the increase in solids. After resolution into these three components, the portion not detectable as reducing material, with the exception of the acclimated sample during the first hour, agrees approximately with the B.O.D. removed from solution during comparable intervals.

It is erroneous to assume, as frequently is done in the case of carbohydrates that lack of acid or gas production indicates biochemical inactivity. Rather the reverse is true, and these soluble materials are capable of utilization in relatively large quantities and frequently at high rates.

It may be stated then that during a 23-hour aeration period, it is immaterial whether a sludge has been acclimated to dextrin or not as measured by over-all removal. In either case 2 to 3 per cent is found in the supernatant, 7 to 8 per cent is recovered from the sludge, and approximately 90 per cent has been completely utilized with the production of a 51 to 55 per cent increase in sludge solids. In the intervening time intervals, however, no such agreement is indicated. In the acclimated sample these 23-hour figures are closely approached in 3 hours, 1.8 per cent is found in the supernatant, 13.9 per cent in the sludge and 84.3 per cent utilized. At 3 hours in the unacclimated sample 46 per cent is found in the supernatant, 7.4 per cent in the sludge and only 46.6 per cent completely utilized. It is quite evident that the rate of removal, though not the total removal, has been altered by the program of previous feedings. About twice as much reducing material is found in the acclimated sludge as in the other until the 23rd hour is reached. At the end of the first hour these figures are 23.2 to 12.5 per cent, from the 2nd to the 5th hour, the amount in the acclimated sludge decreased slowly from 15.7 to 12 per cent and in the other very little change (7.4 to 7.9 per cent) occurs. At 23 hours they are similar at 7.2 to 7.7 per cent.

These differences in removal mechanism then stand out. An acclimated sludge removes approximately the same amount of dextrin from solution in 2 to 3 hours as an unacclimated sludge does between 5 and 23 hours,

producing at the same time proportionate increases in the amount of sludge solids. About twice as much removed material is contained in the acclimated sludge as in the unacclimated sludge until stabilization is reached at some time interval between the 5th and 23rd hour. After 2 to 3 hours any removal in the acclimated sample is at the expense of reducing material contained in the sludge. In the unacclimated sample, it is being removed from the supernatant. Both systems are similar at 23 hours and have produced approximately 50 per cent more solids, the ash content of which has been reduced by about 40 per cent. These solids figures deserve more consideration and will be discussed later.

In view of the considerable interest in *Sphaerotilus natans,* the ability of this organism to utilize various carbohydrates (other than glucose) as sources of food material was investigated. The nutrient materials used were glucose, l-xylose, soluble starch and dextrin. The glucose sample permits a check on previous published data (5). In these tests contamination by other organisms was precluded.

TABLE 6.—Growth Response of Sphaerotilus Natans to Various Carbohydrate Substrates

Carbohydrate	Carbohydrate Feed (p.p.m.)	Initial Solids (p.p.m.)	24-Hour pH	24-Hour Solids (p.p.m.)	Increase in Solids (p.p.m.)
Control	None	5.2	7.7	74	68.8
l-Xylose	1,250	5.2	7.3	72	66.8
Glucose	1,250	5.2	5.7	640	634.8
Dextrin	1,250	5.2	6.9	612	606.8
Soluble Starch	1,250	5.2	6.7	560	554.8

Data obtained are tabulated in Table 6. The growth response of *Sphaerotilus natans* to dextrin and soluble starch as sole sources of energy is comparable to its response to glucose. It seems, however, unable to utilize l-xylose at least within a 22- to 24-hour aeration period. It is probable, however, that in most cases the introduction of a carbohydrate will promote growth of *Sphaerotilus natans* (6).

Solids figures have not been stressed, but reference to any of the tables shows large increases in sludge solids when a carbohydrate feed is used. This fact is so persistently obtrusive that it cannot be ignored, and it possesses real significance. Whenever an activated sludge, which is perfectly normal in all respects, is suddenly subjected to an increase of carbohydrates feed, a fine state of balance is upset. The sludge immediately attempts to adjust itself to this alien feed and soon is consuming it in ever increasing quantities. In itself, this is desirable but, as a necessary corollary, adsorption and assimilation at rapid rates produce enormous quantities of sludge with a low ash content. This sludge production may amount to 50 per cent or better in a 24-hour period (Table 5a). Such increases in solids would seriously affect the equilibrium of the average plant not designed to cope with such a factor. This is not bulking *per se* but simply an unruly sludge production. However, the conditions most favorable for zooglea are also well suited for the growth of *Sphaerotilus natans.* Too, as has been shown in Table 6, all of the carbohydrates studied with the exception of the pentose sugar l-xylose were readily utilized by *Sphaerotilus,* resulting in a rapid increase of that organism. This is an additional hazard.

The effect then on a plant called upon to handle sudden increases in carbohydrates should be a tremendous and perhaps unmanageable increase in sludge solids; this sludge having a greatly decreased ash content. As a complicating factor, conditions conducive to the growth of *Sphaerotilus natans* would exist. Either is undesirable and serious but if the two occur simultaneously the operation of an activated sludge plant will be seriously impaired.

TABLE 7.—Basic Data Alcohols, Aldehydes and Organic Acids

Compound	Synonym	Formula	Molecular Weight	Equivalent Wt. of Oxygen for Oxidation	Theoretical B.O.D. per Mg. per Liter (p.p.m.)	
					Ultimate	5 days
Methyl Alcohol	Wood Alcohol Methanol	CH_3OH	32.03	48	1.50	1.03
Ethyl Alcohol	Ethanol	CH_3CH_2OH	46.05	96	2.08	1.42
Ethylene Glycol	Glycol	$(CH_2OH)_2$	62.05	80	1.29	0.88
Glycerine	Glycerol	$C_3H_5(OH)_3$	92.06	112	1.22	0.83
Formaldehyde	Formalin Methanol	HCHO	30.02	32	1.07	0.73
Formic Acid	Methanoic Acid	HCOOH	46.03	16	0.348	0.24
Acetic Acid	Ethanoic Acid	CH_3COOH	60.05	64	1.07	0.73
Tartaric Acid d or l	Weinsaure	$(CHOHCO_2H)_2$	150.09	80	0.533	0.36
Citric Acid	—	$HO_2CCH_2C(OH)(CO_2H)CH_2CO_2H$	192.12	144	0.750	0.51
Lactic Acid	—	$CH_3CHOHCO_2H$	90.08	96	1.07	0.73
Oxalic Acid	Ethandioic	$(CO_2H)_2 \cdot 2H_2O$	126.07	16	0.127	0.086
Calcium Gluconate	—	$C_{12}H_{22}O_{14}Ca$	430.35	352	0.818	0.56
Ammonium Acetate	—	$C_2H_3O_2NH_4$	77.08	64	0.83	0.56

Alcohols and Organic Acids

Compounds belonging to the classes of alcohols and organic acids studied included methyl and ethyl alcohols, ethylene glycol, glycerine, formaldehyde, ammonium acetate, calcium gluconate and formic, acetic, tartaric, citric, lactic and oxalic acids.

The alcohols and organic acids are quite readily removed from solution with the exception of methyl alcohol and oxalic acid, as will be observed by referring to Table 8. Two initial B.O.D. figures are given, a theoretical and one observed immediately after mixing. Oxalic acid shows no removal of the theoretical, and 37 to 45 per cent removal of the observed B.O.D. With methyl alcohol in the concentrations tried, little removal is evidenced, only 3.6 per cent of the B.O.D. observed after mixing in one case and none in the other. This corresponds to 5.74 per cent and 2.43 per cent of the theoretical initial B.O.D. Calcium gluconate and ethylene glycol are intermediate, showing removal data ranging from 60 to 80 per cent. All of the remaining test materials in this group indicate a B.O.D. removal from solution corresponding to 98 per cent or better in 22 to 24 hours. It is interesting to note also, that in the case of methyl alcohol with a very low amount of B.O.D. removal, there is an 8.5 per cent decrease in solids while the next higher alcohol, ethanol, with a B.O.D. removal of better than 99 per cent, shows an 18.5 per cent increase in solids.

It should perhaps be stated here that while exact norms are not established by oxidation experiments, reasonably accurate behavior expectancies are indicated. Although every attempt has been made to maintain uniform experimental conditions, certain deviations from the normal cannot be avoided. It is not possible, for example, to use exactly the same amount of an identical sludge throughout so many experiments, consequently variations due to

TABLE 8.—B.O.D. Removal Data on Activated Sludge Fed with Alcohols and Organic Acids

Compound Fed	Initial Conc. of Compound Fed in Sludge Liquor (p.p.m.)	Sludge Index	pH		Suspended Solids (p.p.m.)			5-day B.O.D. of Supernatants (p.p.m.)			Percentage of Theoretical Initial 5-day B.O.D. Removed in 22 to 24 Hours	Percentage of B.O.D. Observed After Mixing Removed in 22 to 24 Hours
			Initial	Final	Initial	Final	Indicated Change	Theoretical Initial	Observed Immediately After Mixing	Observed After 22 to 24 Hours		
Methyl Alcohol	997	110.9	7.1	6.8	2,028	1,884	−144	1,027	1,004	968	5.74	3.6
	997	110.9	7.1	6.8	2,024	1,824	−200	1,027	914	1,002	2.43	0.0
Ethyl Alcohol..	1,000	61.0	6.9	5.9	1,736	2,024	+288	1,420	770	6.5	99.5	99.2
	1,000	61.0	6.9	6.1	1,732	2,080	+358	1,420	740	5.1	99.6	99.3
Glycol.....	484	76.4	7.0	5.9	1,256	1,260	+4	426	—	98	76.5	—
	484	76.4	7.0	5.9	1,236	1,256	+20	426	—	112	73.8	—
Glycerine.....	720	—	—	—	2,316	—	—	597.6	497	—	—	—
	720	—	—	—	600	—	—	597.6	497	—	—	—
Acetic Acid....	578	59.1	6.9	5.5	2,068	2,268	+200	422	455	2.6	99.4	99.5
	578	59.1	6.9	5.5	2,132	2,296	+141	422	456	2.8	99.3	99.4
Citric Acid.....	550	62.2	7.3	7.4	2,228	2,264	+36	280	265	4.5	98.4	98.3
	550	62.2	7.3	7.4	2,240	2,324	+84	280	253	4.5	98.4	98.2
Calcium Gluconate...	250	64.6	7.4	6.5	1,428	1,436	+8	138	93	25.3	81.7	72.8
	250	64.6	7.4	6.5	1,448	1,424	−24	138	86	33.0	74.6	61.6
Oxalic Acid....	250	87.7	7.2	6.9	2,044	2,072	+28	21.5	44	27.5	0	37.5
	250	87.7	7.2	6.9	2,048	2,084	+36	21.5	40	22.0	0	45.0

the demands of the test sludge and its particular initial predilection for the test material may occur. However, a reasonable basis is established for predicting whether oxidation of material removed from solution occurs, to what extent and at what rate, and if viewed in this light the data presented in Table 9 are helpful and informative.

Formaldehyde was the only material in this group that showed no evidence of oxidation by activated sludge. It had, in fact, a detrimental effect, less oxygen being used by the formaldehyde fed sludge than by the control sludge. The other materials studied in this group all indicated some measure of oxidation of the material removed from solution. Some are quite regular in performance while others show variability in degree and sometimes in the time interval required for appreciable oxidation. Acids in general are readily oxidized, with the possible exception of oxalic acid, in which contradictory results are apparent. Two samples with activated sludge indicated no oxygen utilization, while one showed progressive oxidation until the 5th hour, 31.9 per cent, and a decline to 12.2 per cent at 22 to 24 hours. With a pure culture sludge a progressive oxidation to 19.9 per cent at 22 to 24 hours took place, the rate, however, being extremely slow until the 5th hour. Formic acid was readily attacked by activated sludge but not by pure culture sludge in the single experiment performed. Lactic acid was readily oxidized by pure culture sludge. Citric acid exhibited one irregularity indicating no oxidation, although a similar sludge on the same day had successfully oxidized 80 per cent of the tartaric acid in 22 to 24 hours. Citric acid also had a tendency to start slowly and to indicate little oxygen utilization until the 5th to 24th hours. Acetic and tartaric acids are readily and very appreciably oxidized, both by activated sludge and by pure culture sludges, although a tendency is evident for pure culture sludges to produce less oxygen utilization during the first 3 to 5 hours. Ammonium acetate is apparently more readily oxidized than acetic acid itself.

TABLE 9.—Oxidation of Alcohols and Organic Acids by Activated Sludge

Compound Fed	Quantity of Compound Fed (p.p.m.)	Quantity of Sludge Used in Experiment	Mg. of O_2 Used in 24 Hours by Control Sludge	Mg. of O_2 Used in Indicated Time in Hours as a Result of Alcohol or Acid Feed				Per Cent of Theoretical Ultimate Demand of Compound Satisfied in Indicated Time in Hours			
				1	3	5	22-24	1	3	5	22-24
Methyl Alcohol	500	3,272	176.2	−8.4	−5.6	7.0	110.0	0.00	0.00	0.93	14.6
	997	2,028	219.2	6.1	—	4.8	41.0	0.41	—	0.32	2.74
	997	2,024	219.2	6.2	—	5.5	35.8	0.41	—	0.36	2.39
Ethyl Alcohol	1,000	1,736	106.3	6.3	37.7	83.5	512.9	0.30	1.81	4.01	24.6
	1,000	1,732	106.3	1.5	29.5	71.5	501.9	0.07	1.42	3.43	24.1
Glycol†	484	1,256	82.7	−2.7	4.1	3.3	48.2	0.00	0.66	0.53	7.72
	484	1,236	82.7	−6.0	5.6	4.4	47.2	0.00	0.90	0.71	7.56
Glycerine	720	2,316	76.0	23.4	87.5	138.7	247.6	2.7	9.96	15.79	28.19
	720	600*	41.9	16.3	66.6	166.4	317.9	1.86	7.58	18.94	36.19
Formaldehyde	720	2,600	107.5	−8.1	−8.7	+2.1	−29.3	0.00	0.00	0.28	0.00
Formic Acid‡	720	2,052	75.0	29.0	43.7	49.5	100.0	11.6	17.4	19.8	39.9
Acetic Acid	716	3,228	246.7	33.2	121.2	150.3	143.5	4.3	15.8	19.6	18.73
	716	610*	41.2	13.9	43.6	139.2	425.1	1.8	5.7	18.2	55.5
	716	768*	55.5	2.0	14.9	35.0	437.2	0.26	1.9	4.6	57.1
	716	2,884	46.9	15.0	46.2	83.2	409.0	1.9	6.0	10.9	53.4
	578	2,068	126.5	23.4	86.9	133.4	190.3	3.8	14.1	21.6	30.8
	578	2,132	126.5	22.2	78.8	122.9	178.9	3.6	12.7	19.9	28.9
Ammonium Acetate	1,000	3,420	70.6	40.2	173.3	308.9	659.0	4.8	20.8	37.0	78.9
Tartaric Acid	720	2,141	133.4	28.4	46.6	96.6	249.8	7.4	12.1	25.0	65.0
	720	2,880	236.0	0.0	62.5	94.8	308.0	0.0	16.3	24.7	80.3
	720	748*	26.2	6.7	2.6	13.6	112.3	1.7	0.67	3.5	29.3
	720	768*	37.9	5.1	12.9	19.0	221.2	1.3	3.4	5.0	57.6
Citric Acid	720	2,141	133.4	12.2	10.2	29.9	164.8	2.3	1.9	5.5	30.4
	720	2,880	236.2	−14.3	−24.7	−28.1	−158.0	0.0	0.0	0.0	0.0
	550	2,228	158.7	−6.4	−3.0	7.2	26.9	0.0	0.0	2.5	9.2
	550	2,240	158.7	−0.9	15.4	25.3	44.0	0.0	5.3	8.6	15.0
	720	748*	26.2	3.3	1.4	0.0	80.2	0.61	0.26	0.0	14.9
Lactic Acid	720	768*	37.9	13.4	54.4	80.1	320.9	1.7	7.1	10.4	41.7
	720	748*	26.2	14.2	28.2	42.5	535.3	1.8	3.7	5.5	69.5
Ca Gluconate	250	1,428	98.0	−3.3	18.0	18.9	27.9	0.0	8.8	9.2	13.6
	250	1,448	98.0	−5.3	18.5	19.3	28.1	0.0	9.0	9.4	13.7
Oxalic Acid	250	2,044	101.6	−0.1	−1.2	−12.8	−18.3	0.0	0.0	0.0	0.0
	250	2,048	101.6	−3.4	+2.2	−13.3	−24.4	0.0	0.0	0.0	0.0
	720	2,780	132.8	5.5	18.1	29.0	11.1	6.0	19.7	31.9	12.2
	720	226*	28.4	0.5	—	5.0	18.1	0.55	—	5.5	19.9

* Pure culture zoogleal sludge was used.

† Glycol was not oxidized by pure culture zooglea.

‡ Formic acid was not attacked by pure culture zoogleal sludge in the single experiment performed.

Whether this is due to the additional nitrogen introduced with the salt has not been determined.

Of the acids studied then, all were capable in varying degree of being oxidized by activated sludge. There is an apparent tendency for this oxidation to proceed slowly, using oxalic and citric acids for the first 3 to 5 hours. When pure culture sludges are used this tendency is apparent with all acids used. The amount of oxidation is at least as great as is found with carbohydrates, and in the case of lactic, tartaric and acetic acids, greatly exceeds the rates with carbohydrates.

Glycerine is apparently the most easily oxidized alcohol. It is the only one studied that is oxidized to any appreciable extent in the first hour. Neither methyl alcohol nor ethylene glycol are oxidized to any significant extent to the 5th hour. Ethylene glycol is not attacked at all by pure culture zoogleal sludge. At 22 to 24 hours ethyl alcohol and glycerine are being actively oxidized, 24 per cent in the former case, and 29.0 to 37.2 per cent in the latter. This compares with about 7.5 per cent for ethylene glycol. Methyl alcohol indicates a 2.7 to 14.6 per cent oxidation of the material removed from solution but reference to Table 8 shows that a very limited amount was actually removed from solution.

Generalizing from the materials studied it would seem that the alcohols are not as readily oxidized as the organic acids.

Amino Acids, Proteins and Miscellaneous Compounds

In Table 11, data on the removal of B.O.D. from substrates containing various amino acids and miscellaneous compounds are presented. The amino acids are quite readily removed from solution. The removal in 22 to 24 hours is approximately 90 per cent or better with all amino acids studied except tyrosine and cystine. The indicated removal of 5-day B.O.D. with tyrosine amounts to about 30 per cent. Cystine shows no removal of the 5-day B.O.D. observed immediately after mixing. Castile soap is also readily removed from solution, to the extent of about 90 per cent in 22 to 24 hours. Gelatin is not quite as effectively removed, the percentage being approximately 80 per cent in the same time interval. Soap is remarkable also, in that approximately

TABLE 10.—Basic Data—Amino Acids, Proteins and Miscellaneous Compounds

Compound		Formula	Molecular Weight	Equivalent Weight of Oxygen for Oxidation	Theoretical Carbonaceous B.O.D. per Mg. per Liter (p.p.m.)	
Common Name	Scientific Name When Known, or Synonym				Ultimate	5-day
Glycine	a-amino acetic acid	NH_2CH_2COOH	75.07	48	0.64	0.44
Alanine	a-amino propionic acid	$NH_2CH(CH_3)\cdot COOH$	89.09	96	1.08	0.74
Glutamic Acid	a-amino glutaric acid	$HOOC\cdot CHNH_2(CH_2)_2COOH$	147.13	144	0.98	0.67
Tyrosine	B-(p-hydroxyphenyl) a-amino propionic acid	$HO\cdot C_6H_4\cdot C_2H_3(NH_2)COOH$	181.18	304	1.68	1.15
Cystine	BB′-di-thio-di-(a-amino propionic acid)	$(HOOC\cdot CH(NH_2)CH_2S)_2$	240.29	176	0.73	0.50
Peptone	Poly peptide	—	—	—	1.03	0.70
Meat Extract	Mineral salts and peptones	—	—	—	0.47	0.32
Gelatin	—	—	—	—	0.98	0.67
Olive Oil	—	—	—	—	0.153	0.10
Soap	Sodium oleate	$CH_3(CH_2)_7CH{:}CH(CH_2)_7COONa$	304.45	800	2.14	1.46
Mineral Oil	—	—	—	—	0.012	0.008
Potassium Cyanide	—	KCN	65.10	—	—	—
Urea	Carbamide	$NH_2\cdot CO\cdot NH_2$	60.06	0	0	0
Acetonitrile	Methyl cyanide	CH_3CN	41.05	64	1.56	1.07
Thioacetamide	Aceto-thioamide	$CH_3\cdot CS\cdot NH_2$	75.13	75	1.00	0.68
Thioglycolic Acid	—	$HS\cdot CH_2\cdot COOH$	92.11	64	0.69	0.47

TABLE 11.—B.O.D. Removal Data on Activated Sludge Fed with Amino Acids and Miscellaneous Compounds

Compound Fed	Initial Conc. of Compound Fed in Sludge Liquor (p.p.m.)	Sludge Index	pH		Suspended Solids (p.p.m.)			5-day B.O.D. of Supernatants (p.p.m.)			Percentage of Theoretical Initial 5-day B.O.D. Removed in 22 to 24 Hours	Percentage of B.O.D. Observed After Mixing Removed in 22 to 24 Hours
			Initial	Final	Initial	Final	Indicated Change	Theoretical Initial	Observed Immediately After Mixing	Observed After 22 to 24 Hours		
Glycine	720	—	7.2	6.5	2,196	2,924	728	317	326	42.6	86.6	86.9
Alanine	500	83	6.6	6.9	1,296	1,416	120	370	327	14.0	96.2	95.7
	500	83	6.6	6.9	1,316	1,452	132	370	310	12.5	96.6	96.0
Glutamic Acid	500	79.8	6.8	6.9	1,504	1,692	188	335	275	6.2	98.1	97.7
	500	79.8	6.8	6.9	1,504	1,736	232	335	300	6.7	98.0	97.8
Tyrosine	500	53.2	6.6	5.7	1,848	1,920	72	575	540	400	30.4	25.9
	500	53.2	6.6	5.8	2,072	2,152	80	575	540	398	30.7	26.3
Cystine	1,000	50.8	6.6	5.7	2,876	2,720	−150	500	48	67	86.6	0
	1,000	50.8	6.6	5.6	2,832	2,580	−252	500	34	46	90.8	0
Peptone*	720	—	7.4	6.5	2,172	2,508	336	504	583	10.0	98.0	98.3
	720	—	7.4	7.0	1,260			504				
Gelatin	1,025	38.8	5.8	7.2	1,396	1,660	264	687	570	128	81.4	77.5
	1,025	38.8	5.8	7.2	1,422	1,652	230	687	560	123	82.1	78.0
Olive Oil	916	49	6.9	6.1	3,372	3,828	456	95	—	—	—	—
	916	49	6.9	6.1	3,260	3,700	440	95	—	—	—	—
Soap**	1,000	48.4	6.9	6.7	2,832	3,108	276	1,710	408	49	97.1	88.0
	1,000	48.4	6.9	6.5	2,832	3,168	336	1,710	420	19.5	98.9	95.4
Mineral Oil	1,000	39.3	7.1	5.5	3,036	3,184	268	8.2	—	—	—	—
	1,000	39.3	7.1	5.5	2,916	3,136	220	8.2	—	—	—	—
Acetonitrile	490	61.0	7.0	6.7	2,516	2,516	0	524	20.5	17.0	96.7	17.1
	490	61.0	7.0	6.7	2,548	2,564	16	524	15.5	21.0	96.0	0
Thioacetamide	1,000	76.0	6.9	6.7	1,768	1,848	80	680	0	0	100	0
	1,000	76.0	6.9	6.7	1,768	1,856	88	680	0	0	100	0
Thioglycolic Acid	662	78.8	6.8	6.4	1,764	1,736	−28	311	0	0	100	0
	662	78.8	6.8	6.4	1,808	1,748	−60	311	0	0	100	0

* Pure culture sludge used. ** Castile soap assumed to be sodium oleate in calculating theoretical B.O.D.

75 per cent of the theoretical initial 5-day B.O.D. is adsorbed and not detectable in the substrate immediately after mixing. B.O.D. data for acetonitrile, thioacetamide and thioglycolic acid are illustrative of the toxic nature of these substances which inhibits their removal from solution biochemically.

With the exception of cystine, the amino acids are quite readily oxidized, comparing in magnitude of oxidation more closely to the carbohydrates than with the organic acids and alcohols. Cystine is quite different, however. Of the two trials made, one shows no increase in oxygen consumption due to the cystine added and the other, while showing a slight increase of 1.5 per cent at 1 and 3 hours, diminished to 0.75 per cent at 5 hours and none at 22 to 24 hours. Obviously little, if any, oxidation occurs.

With tyrosine oxidation proceeds very slowly to the 5th hour, but at 22 to 24 hours about 12 to 13 per cent of the tyrosine that has been removed from solution is oxidized. Gelatin exhibits a similar slow oxidation until the 5th hour and then an appreciable increase to 22 to 34 per cent in 22 to 24 hours. The more heterogeneous materials, peptone and meat extract, are apparently more easily and completely oxidized.

Two oils were used as test materials: olive oil and mineral oil, S.A.E. 30. Strict interpretations are difficult because of lack of satisfactory ultimate

TABLE 12.—Oxidation of Amino Acids, Proteins and Miscellaneous Compounds by Activated Sludge

Material Fed	Quantity of Material Fed (p.p.m.)	Quantity of Sludge Used in Experiment (p.p.m.)	Mg. of O_2 Used in 24 Hours by Control Sludge	Mg. of O_2 Used in Indicated Time (hours) as a Result of Material Fed				Per Cent of Theoretical Ultimate Satisfied in Indicated Time			
				1	3	5	22 to 24	1	3	5	22 to 24
Glycine	720	2,884	46.9	14.8	47.4	66.1	269	3.2	10.3	14.3	58.4
	720	2,316	76.0	11.2	34.7	48.3	194.3	2.4	7.5	10.5	42.2
*	720	768	55.5	0	13.5	29.3	237.1	0	2.9	6.4	51.5
*	720	600	32.9	12.3	49.5	90	270.7	2.7	10.7	19.5	58.7
Alanine	500	1,296	63.6	0	13.2	25.8	183.4	0	2.45	4.78	33.95
	500	1,316	63.6	4.1	32.1	42.1	209.0	0.76	5.95	7.80	38.70
Glutamic Acid	500	1,504	98.9	5.1	21.7	46.6	103.1	1.04	4.43	9.52	21.50
	500	1,504	98.9	16.6	24.0	33.8	152.7	3.39	4.90	6.90	31.15
Tyrosine	500	1,848	59.7	0	3.2	13.6	114.4	0	0.38	1.62	13.61
	500	2,072	59.7	0	0	0	103	0	0	0	12.27
Cystine	1,000	2,876	155.4	0	0	0	0	0	0	0	0
	1,000	2,832	155.4	11.1	11.5	5.5	0	1.52	1.58	0.75	0
Peptone	720	3,308	56.1 (5 hrs.)	45.9	132.7	213.2	—	6.2	17.9	28.7	**
*	720	1,260	15.8	48.3	150.2	227.5	376.5	6.5	20.3	30.7	50.8 **
Meat Extract*	720	1,260	15.8	47.2	93.9	149.8	171.2	14.36	28.58	45.59	52.10**
	720	3,308	150.8	59.7	131.4	259.2	495.7	18.17	39.99	78.88	150.85**
Gelatin	1,025	1,396	110.8	0	—	0	227.7	0	—	0	22.60**
	1,025	1,424	110.8	0	—	3.2	342.1	0	—	0.31	33.95**
Olive Oil	916	3,372	199	0	0	16.8	94	0	0	11.87	71.38**
	916	3,260	199	1.0	10.0	26.9	60.2	0.7	7.06	19.01	42.55**
Soap	1,000	2,832	205.4	0	23.0	47.2	50.8	0	1.08	2.22	2.38**
	1,000	2,832	205.4	27.1	73.1	124.8	191.6	1.27	3.42	5.82	8.96**
Mineral Oil	1,000	3,036	243.2	0	0	0.8	16.5	0	0	6.66	137.5**
	1,000	2,916	243.2	0	3.8	2.2	13.1	0	31.4	18.33	109.2**
Acetonitrile	490	2,516	117.7	0	0	0	0	0	0	0	0
	490	2,548	117.7	0	0	0	0	0	0	0	0
Thioacetamide	1,000	1,768	72	—	6.5	0	0	—	0.65	0	0
	1,000	1,948	72	—	0	0	0	—	0	0	0
Thioglycolic Acid	662	1,764	142.5	20.5	20.4	9.8	0	4.48	4.46	2.14	0
	662	1,808	142.5	17.4	20.1	9.2	0	3.82	4.39	2.01	0
Potassium Cyanide	480	2,600	107.5	0	0	0	0	—	—	—	
Urea	1,200	2,316	76.0	0.2	1.9	3.5	11.3	Theoretically, hydrolysis and not oxidation occurs.			
*	720	768	72.6	11.7	3.4	2.2	17.1				
*	720	600	32.9	1.7	2.8	2.3	2.2				

* Pure culture sludge.

** Ultimate demand computed from actual B.O.D. determinations obtained.

demand figures. Certain conclusions may be drawn, however. Oxidation does occur in a 22- to 24-hour period. This oxidation is of rather small magnitude to the 3rd hour and it appears that a lag phase is involved.

Soap, which would be normally present as a constituent of sewage, is not too readily oxidized in the low concentrations employed for test purposes. Despite the fact that reference to Table 11 indicates a removal from solution of 97 to 99 per cent of the B.O.D. due to the added soap in 22 to 24 hours, only 2.38 per cent is oxidized in one experiment and 8.96 per cent in another.

Urea is apparently simply hydrolized, resulting in the production of free amonia which accumulates to raise the pH. It does not measurably increase the carbonaceous demands or the oxygen utilization on non-nitrifying sludges.

A number of compounds, acetonitrile, thioacetamide and potassium cyanide, show no increase in oxygen utilization. Thioglycolic acid initially shows a small increase in the oxygen used, 3 to 4 per cent, but this soon declines to about 2 per cent at five hours and to none at all at 22 to 24 hours. These latter compounds are all apparently detrimental to the activated sludge.

Discussion

Wastes vary greatly in composition and intensity. Any or even a majority of the materials considered in this paper might be found as constituents of any given waste. From even the most casual inspection of the data given, it will be evident that complex relationships must be at work in the catabolism of organic matter by activated sludge. Certainly the nature of the organic material used is a limiting factor in that it controls extent and manner of utilization. Some materials, of course, especially those containing SH, CHO, or CN groups are definitely detrimental. This is true also of various metallic ions not considered here.

The various organic materials may be classified according to chemical nature, and generalities made from these divisions. However, great variability will be evident even within these classes. Activated sludge responds quite differently to methyl than to ethyl alcohol, for example. Probably the greatest similarity is evidenced by the carbohydrates. L-xylose in some respects is quite dissimilar to the other carbohydrates studied, with respect to its behavior in an activated sludge system and also in its ability to stimulate the growth of *Sphaerotilus natans*.

Another determining factor is, of course, the sludge itself. We are dealing with living things when we use activated sludge and though we can formulate certain rules and be assured that they will hold true in most cases, we cannot always be certain of that strict and complete adherence that is found in a distinctly chemical reaction.

Variations will appear and, although this is at times undesirable, it also has its beneficial aspects. It certainly adds to the versatility of the sludge so that it will attack and utilize a complex variety of materials. If it initially is unable to do so to any great extent in many cases, and more particularly so with carbohydrates, it will adjust itself to do so. This adjustment itself may be undesirable, in part, as witness the large increase in solids with carbohydrates, but essentially it is desirable, increasing the rates of removal and the consequent capacity of an activated sludge for removing carbohydrates from solution in shorter time intervals. The ability to predict its occurrence should make it controllable.

It is impossible to say from the data accumulated for this paper just what does happen, whether a selective change in organisms, or an enzymatic reaction or both occurs. The rapidity of the acclimatization suggests the for-

mation of adaptive enzymes. For practical purposes, however, mere knowledge of the phenomena should suffice.

In the case of dextrin, the carbohydrate receiving the most detailed study, this adaptive mechanism increases the percentage of B.O.D. removal in a 3-hour period from approximately 40 per cent to about 80 per cent, producing at the same time, however, nearly three times as great a solids increase. This increase will occur anyway, of course, with equivalent decreases in substrate B.O.D. In other words, equivalent amounts of dextrin utilized, regardless of time, should produce the same amount of sludge solids.

It has been repeatedly demonstrated that the presence of carbohydrates in the substrate feed leads to a transient deposition of material within the cell (7). However, this maximum increase in solids with an acclimated sludge occurs at intervals somewhat comparable to the detention periods used in practice, falling off slightly thereafter. It should be noted that acclimatization of activated sludge in the presence of sufficient carbohydrate material is unavoidable. With an unacclimated sludge, this maximum increase will not occur until the 24th hour is approached.

Ease of removal of B.O.D. from solution is more likely a function of the individual compound than of the class to which it belongs and, of course, is dependent incidentally on the characteristics of the sludge used. This removal is accomplished by several procedures—adsorption, oxidation, assimilation and synthesis—all occurring concurrently but varying in proportion with the time interval and the substrate material.

Each grouping of the compounds studied shows some with a B.O.D. removal amounting to 90 per cent or better in 22 to 24 hours. But there are deviations from this in each group. With carbohydates it is l-xylose. It is true that it has been shown that adaptive precedures make l-xylose metabolism comparable to that of the other carbohydrates, but initially it is different. With organic acids, oxalic acid and calcium gluconate show lesser removal; with alcohols it is methyl alcohol and ethylene glycol; with amino acids, tyrosine. Neither does rate of B.O.D. removal indicate infallibly to what extent oxidation may occur. The rate of oxidation is subject to great variations and each material is attacked in a different way. This has been observed on numerous occasions using specific organisms and amino acids, organic acids, alcohols and carbohydrates as substrates (8).

Although activated sludge consists of a tremendously varied flora and fauna and is capable of directional development in various ways under the stimulus of specific substrates, the necessary factors may not be initially present in quantity. Whether it means selective development of specific strains of organisms, or production of certain enzymes, a lag phase may ensue with definite substrates. This is particularly true of certain organic and amino acids and the oils. Since it frequently amounts to 5 or more hours and is longer than ordinary detention periods, it is of significance. This undoubtedly accounts for some of the results with pure culture zoogleal sludges which do not attack ethylene glycol at all, and which show a trend to slow rates of oxidation during the first 3 to 5 hours with organic acids.

Summary

Data pertaining to the removal from solution, oxidation, and conversion to protoplasm by activated sludge, of 36 pure organic substances are presented. The materials used represent a wide range of compounds, namely, sugars, alcohols, aldehydes, organic acids, amino acids, and miscellaneous com-

pounds. The data presented are designed to show the response of activated sludge to these materials under average conditions, and not necessarily to determine the criteria of optimum utilization.

Ease of removal of B.O.D. from solution is shown to be more likely a function of the individual compound than of the class to which it belongs and, of course, is dependent incidentally on the characteristics of the sludge used. This removal is accomplished by several procedures—adsorption, oxidation, assimilation and synthesis—all occurring concurrently but varying in proportion with the time interval and the substrate material.

Certain pertinent facts concerning the behavior of carbohydrates when introduced into an activated sludge system are demonstrated. There is an immediate adsorption of carbohydrate varying from 4.7 per cent with l-xylose, glucose and lactose to 30 to 80 per cent for dextrin and starch. It is shown also that the 5-day B.O.D. removed from solution in 24 hours is in excess of 90 per cent with all carbohydrates tested with the exception of l-xylose. The data presented indicate, additionally, that activated sludge can be acclimated to all carbohydrates studied and that this procedure will increase the over-all removal of l-xylose from solution, in 24 hours, from 50 to 60 per cent to about 98 per cent. It is further demonstrated that only a very small portion of these materials, which are so rapidly removed from solution, is oxidized.

Using the complex carbohydate, dextrin, a comprehensive study of the effects of acclimatization was made by determining the partition characteristics of the dextrin between the supernatant, sludge and the unrecoverable carbohydrate which had been completely utilized.

The ability of all carbohydrates studied, with the exception of l-xylose, to promote growth of the filamentous organism *Sphaerotilus natans* is demonstrated.

The alcohols, amino acids and organic acids studied are shown to be quite readily removed from solution, with the exception of methyl alcohol, tyrosine and oxalic acid. All of these compounds are capable of being oxidized by activated sludge although to varying degree. Oxidation takes place readily with all amino acids studied with the exception of cystine, with which no oxidation occurs. Materials such as peptones and meat extract are shown to be more completely and easily oxidized, while soaps and oils are oxidized to only a minor extent. Certain compounds, especially those containing the groupings HS and CN, are not oxidized and are detrimental to sludge, while compounds such as urea are simply hydrolyzed.

Eliminating from consideration those compounds in each class that were not readily attacked by activated sludge, the data indicate the following general principle. After 24 hours of aeration with activated sludge from 90 to 99 per cent of the compound will be removed from solution and disposed of as follows for the following classes:

Class	Per Cent Oxidized		Per Cent Converted to Protoplasm (Organized Sludge)
	Range	Mean	
Carbohydrate	5 to 25	13	65 to 85
Alcohol	24 to 38	30	52 to 66
Amino Acid	22 to 58	42	32 to 68
Organic Acid	30 to 80	50	10 to 60

In other words, in general, organic acids produce the smallest yield of activated sludge and carbohydrates the largest, with the alcohols and amino acids intermediate in sludge production. This explained why there is such a stimulation in sludge production when large quantities of carbo-

hydrate wastes are added to sewage being treated by the activated sludge process.

It is demonstrated also that normal activated sludge, when subjected to an increase of carbohydrate feed, will become quickly acclimated and, because of adsorption and assimilation at rapid rates, will produce enormous quantities of sludge with a low ash content. This factor should constitute an important consideration in the design of plants where this condition is likely to occur due to seasonal discharges of cannery wastes, corn or sugar products or similar materials.

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GROUND GARBAGE—ITS EFFECT UPON THE SEWER SYSTEM AND SEWAGE TREATMENT PLANT *

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The purpose of this paper is to review the records, as far as possible, of sewage treatment plants in actual operation where all the garbage, except that collected by private scavengers, is ground and treated with the sewage solids at the plant. It is high time that such an appraisal was made. If the record is good, the engineering profession should know it, and if it is bad, this likewise should be known and the idea of dual disposal discouraged in future designs.

Eleven years have elapsed since the first large garbage grinding experiment was undertaken at Indianapolis, Indiana. Since many basic data were collected at that test, the writer must refer to this work in undertaking another review of this interesting subject. Unfortunately, at no plant where garbage is now being ground have determinations been made regarding the various constituents of the garbage, as was done at Indianapolis, and therefore, in making various calculations, it has been necessary to use Indianapolis figures (1).

Household Grinders

Several methods may be used for grinding of waste food products for introducing into the sewer system. One is by means of the home grinder, attached to the sink in each house, where the wastes are ground as produced, and flushed out to the street sewer via the regular household drain. One unit for this use is the General Electric "Disposall," described by Cohn (2) as follows:

"The Disposall consists of a shredding compartment of about 3 qt. capacity and a ¼ HP motor which shreds the material into a uniform, finely shredded pulp, to a size that will flow through clearances of under 1/16 in. . . .

"Water for grinding is supplied from the sink faucet, thus providing a system free from cross connections. The unit switch is actuated by placing the cover on the grinder opening in the sink and turning the handle to the 'on' position. The unit runs only when the cover is safely locked in place.

"In ordinary use, for grinding all kinds of food wastes, including bones but not inert materials such as glass, crockery, etc., the Disposall operates approximately one minute per capita per day. Extended minute-counter readings in one home indicate a per capita operation period of less than one-half minute per day.

"Thus, the water use for grinding at a rate of 1½ to 2 g.p.m. is between 1 and 2 gallons per capita per day. This figure is important to remember when analyzing the effect of food waste grinding on sewage flow, on sewer loadings and on plant volumes."

Take for example a city of 100,000 people with 3½ persons per family, and assume that this city is completely equipped with Disposalls. Assume further that the garbage amounts to 0.5 lb. per capita per day with a total solids content of 25 per cent and that the average sewage flow is 10 m.g.d. The number of grinders would be 28,600 and the flow of pulped garbage would be about 0.15 m.g.d., or an increase of 1.50 per cent in sewage volume.

In regard to effect of this material on the house and city sewers, Cohn has this to say: "It is the consensus of

* Presented at 20th Annual Meeting, Pennsylvania Sewage Works Assn., State College, Pa., August 28–30, 1946.

opinion that house grinders produce no stoppage in drain lines. In fact, the bulk of testimony is that former sluggish drains are no longer sluggish, due to the high speed scouring action of the home grinder unit."

At Schenectady, New York, where some 400 to 500 Disposalls are in use, the city inspector of plumbing reports no stoppage from home grinder units.

Central Grinding Stations

Garbage may also be introduced to the public sewers at central grinding stations located at strategic spots on the city's sewer system. Under the conditions of the hypothetical problem, it is found that the total increased flow of pulped garbage from central grinding stations is 25 (tons of garbage) $\times$ 700 (gal. per ton) = 17,500 g.p.d. which represents an increase of 0.18 per cent in the sewage flow. This volume is so small as to be negligible in the design of sewers.

As to the effect of the ground garbage on the sewer system, there need be no fear of stoppage occurring from this material. Combined sewers are designed for minimum velocities of approximately 3 ft. per sec., and since the grinding stations would be located only on the larger sewers, the velocities and the volume of flow would be sufficient to prevent stranding of solids. Local conditions should always be studied, but with a proper site chosen to insure a sufficient velocity and volume of flow in the receiving sewer, a grinder selected to allow only garbage solids of a certain maximum size to be discharged into the sewer, and by control of the feed to the grinder to keep out heavy non-organic matter, there can be certainty that no sewer stoppages will result. Garbage grit, amounting to approximately 40 lb. per ton of garbage, must be waterborne to the treatment plant (unless it is removed by special apparatus), but since the size of particles will be smaller and their specific gravity lower than the largest and heaviest particles of sand and gravel now carried by sewers, there should be no undue alarm because of the addition of a smaller amount of lighter and more easily transportable garbage grit. Garbage grit will probably not exceed 1.0 cu. ft. per m.g. where garbage is added to the sewage at a rate of 1.0 ton per m.g.

If garbage is discharged into combined sewers, there may be some overflow of this material during storms at the controls to the interceptor, but since this will occur only during storms, when dilution is high, it is not believed that the additional pollution of the watercourse will be appreciable.

Grinding stations can be of very simple design, where small tonnages are ground, or quite elaborate where large tonnages are expected. The station shown in Figure 1 shows a grinder

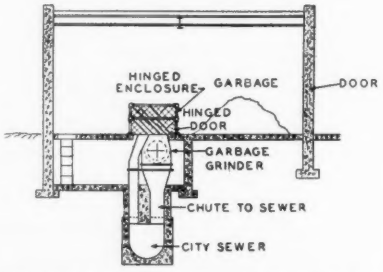

FIGURE 1.—Garbage grinding station with manual feed to grinder.

built directly over a sewer, above which is a receiving floor and building. Garbage is dumped from trucks directly onto the floor and is fed to the grinder manually by an operator with a rake, who pushes the garbage through a swinging trap door into an enclosure directly over the grinder. The operator picks out large bones, tin cans, glass bottles, or other large inorganic items, before grinding. These are placed in cans to be hauled away later to the refuse dump.

For larger stations, the design shown in Figure 2 is recommended. Here the garbage is dumped into a pit hold-

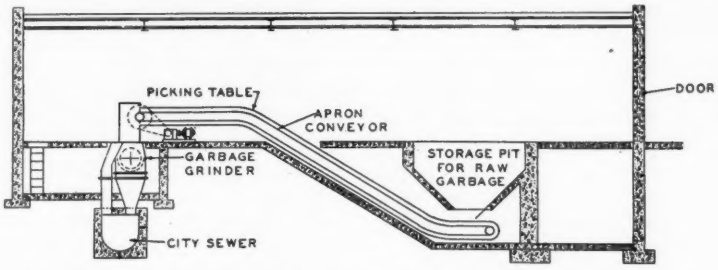

FIGURE 2.—Garbage grinding station with mechanical feed to grinder.

ing several tons of garbage. This pit is equipped with a conveyor designed to feed the grinder uniformly. Just before the conveyor discharges into the grinder, a horizontal portion of the feeder serves as a picking table where an operator is stationed to pick off any material which should not pass to the grinder.

If removal of grit seems desirable, the layout shown in Figure 3 is recommended. The grinder can either be fed by hand or by mechanical means and the ground pulp dropped into a washer which will separate the grit from the organic matter and allow the ground garbage to overflow directly to the sewer. The garbage grit passes to the boot of the dewatering elevator which is a part of the washer, where it is automatically picked up and elevated to the grinding floor. This material will be disposed of along with the nongrindable material picked out of the raw garbage.

Garbage grinding stations properly designed should not be objectionable. Exterior architecture should harmonize with the neighborhood, grounds should be landscaped to present a pleasing appearance, and doors and windows should be tight. Garbage should be dumped and ground only when doors and windows are closed. Fans should constantly exhaust the inside of the building and the air be put through activated carbon containers, ozone, or any other means of purifying the air. These two methods are now in use in some sewage treatment plants. Another possibility of odor control would be to pass the exhaust air through a furnace where temperatures of 1,200° F. are maintained, before passing to a stack. If sufficient thought is given to the design of these stations, it the writer's belief that they can be located any place in the city. True, these features will cost money, but it is believed that the overall eco-

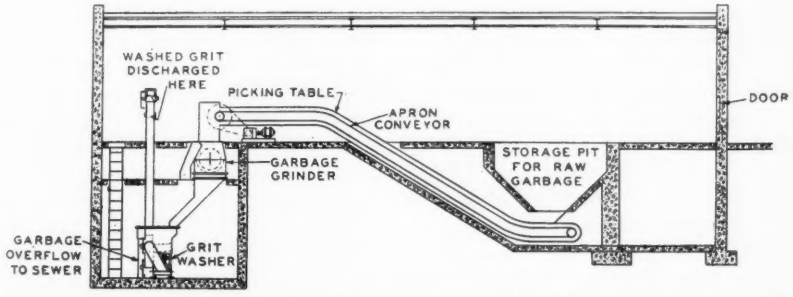

FIGURE 3.—Garbage grinding station with mechanical feed to grinder and with Jigrit washer for removal of grit.

nomic savings will far outweigh the added costs.

The principal advantage in grinding garbage at central stations is an economic one. Garbage added to the sewage at these stations is waterborne to the sewage plant and every mile saved by this means of transportation means that much saved in haulage costs. For example, a study at Indianapolis in 1935 showed that for every mile saved in hauling of one ton of garbage there was a saving of $0.20. If, for example, in the hypothetical city of 100,000 people, two central stations could be built, resulting in a saving in haul per day of 2 miles to each station, this would result in an annual saving of $3,650, or mean a reduction of $0.40 per ton in the cost of disposal of garbage.

There may be other savings in collection costs, such as the rerouting of trucks to the grinding station, but these cannot be determined until careful engineering studies of this phase of the problem have been made. Another advantage, especially in the larger cities, is that of levelling out the organic load at the sewage plant. The greater the distance from the plant to the grinding station, the more this will be true. For still further levelling out of this load, collection of garbage and grinding of same could be done at night. If this material is added so as to arrive at the plant at time of low flow and strength, it could be made to produce sewage of much more uniform strength than, as a rule, prevails today. This would be of considerable advantage, as any operator knows that many headaches could be eliminated if he could handle sewage of uniform strength 24 hours a day. This does not imply that addition of ground garbage will give a sewage of completely uniform strength, but it could be made to lessen the valleys in strength that now occur in the early morning hours at most plants.

Garbage Grinding at the Sewage Treatment Plant

If garbage is ground at the treatment plant, it can either be added to the raw sewage directly ahead of the grit channels, or it can be ground and added directly to the digesters. If the former is used, garbage grit will be removed by the grit channel at the plant, but if garbage is added directly to the digesters, in general, it is believed that facilities should be provided for first removing the garbage grit. This can be accomplished by several means: (1) by passing the garbage mixture through an ordinary grit channel with enough water so that its solids content will not be more than 4 or 5 per cent; (2) by providing a garbage pit equipped with air agitation, to which the garbage is added with enough water to bring its solids content down to approximately 5 per cent and, after agitation with air for a few minutes, pumping the top liquor to the digester and the material in the bottom of the pit to the plant grit chamber; (3) by passing the mixture through a grit washer as shown in Figure 3, with the overflow passing to a wet well from which the slurry is pumped to the digesters.

An example of the second method is the garbage pit at Marion, Indiana, built in May, 1943 (4). The well of about 4,000 gal. effective capacity was made by partitioning off a portion of the wet well in the sewage pumping station. The well can store about 4 tons of green garbage with a 5 per cent solids content. As the pH of ground garbage drops rapidly, especially in the summer, lime is added to the pit for pH control unless the garbage is promptly pumped to the digester.

At Findlay, Ohio, all of the garbage is added directly to the raw sewage, and therefore the garbage grit settles in the plant detritor. Grit per million gallons of sewage before garbage was added averaged 1.5 cu. ft., and since grinding 2.7 cu. ft. This indicates that

the garbage grit equals 1.3 cu. ft. per m.g. of sewage when garbage additions are at a rate of 1.1 tons per m.g. of sewage. This increase is assumed at being entirely from garbage, while other factors may actually have accounted for part of it.

At Marion, Indiana, the reason for changing to direct addition of garbage to the digesters was a belief that this would result in pumping of less sludge to the digesters and probably give less supernatant solids from the digesters to the plant influent. The record before and since this change was made is given in Table 1. Excluding the period of September, 1940 to June, 1941, when the plant was starting up, the gallons of waste sludge per 100 p.p.m. of suspended solids in the raw sewage are found to be about the same whether garbage solids are discharged to the primary tanks or whether they go directly to the digesters. Certainly these records indicate no advantage in pumping of garbage solids directly to the digesters. The supernatant appears to have been reduced considerably by direct addition to the digesters, but this was caused by a method of plant operation whereby during this period large quantities of dilute sludge were hauled out and applied to nearby farms as liquid fertilizer, thus reducing the supernatant returned to the head of the plant. During this period some of the monthly records show zero gallons of supernatant, as the quantities of withdrawn sludge and supernatant were equal.

TABLE 1.—Record of Raw Sludge To and Supernatant From Sludge Digestion Tanks at Marion, Indiana

Period	Garbage Added to Sewage in Tons per Million Gallons	Raw Sludge to Digesters in Gallons per 100 P.P.M. of Suspended Solids in Raw Sewage	Gallons of Supernatant from Digesters per Million Gallons of Raw Sewage
September, 1940 to June, 1941	None	4,400	7,220
June, 1941 to September, 1941	1.0*	2,300	2,980
September, 1941 to September, 1942	0.8*	3,190	7,900
September, 1942 to May, 1943	0.6*	3,010	13,800
Average	0.8	2,810	7,700
May, 1943 to January, 1944	1.0**	3,515	10,350
1944	0.7**	2,325	2,260
1945	0.7**	2,630	1,070
Average	0.8	2,860	4,000

* Garbage added directly to raw sewage.
** Garbage added directly to digesters but waste sludge figures include garbage.

The plants at Findlay, Ohio, from January, 1939 to date, and at Marion, Indiana, from September, 1940 to May, 1943, are typical examples of garbage addition ahead of the plant, while since May, 1943 the garbage at Marion has been pumped directly to the digesters after first passing through an air-agitated holding tank.

Calculated Increases in Strength of Sewage from Ground Garbage

The increase in strength of raw sewage from garbage is, of course, dependent upon the pounds added and the nature of the garbage solids. In this there appears to be a great divergence of opinion and far too little actual data upon which to make reliable estimates. At Indianapolis, after trying many methods of sampling raw garbage, the one which gave dependable results showed that the garbage contained 17.5 per cent solids. Some writers have used 20, 25, and even 30 per cent. More agreement is found on the pounds of garbage per capita per day. The customary figure is 0.5 lb. per day, although this figure may be only 50 per cent of the annual average during winter months, and 100 per cent higher during the late summer and early fall months. This figure of 0.5 lb. per capita should be used only in the absence of local information, because in some places this is known to be low and in other places it is too high.

Attention is called to the fact that

TABLE 2.—Increases in Strength of Raw Sewage Due to Addition of Garbage of Varying Total Solids Content but with Garbage Added at a Constant Rate

Solids in Green Garbage (%)	17.5	20.0	25.0	30.0
Garbage, Total Solids (lb./cap./day)	0.088	0.100	0.125	0.150
Garbage, Suspended Solids (lb./cap./day)	0.065	0.074	0.093	0.111
Garbage, B.O.D. (lb./cap./day)	0.038	0.043	0.055	0.065
Tons of Garbage per M.G. Sewage	2.50	2.50	2.50	2.50
Increase in Sewage Suspended Solids (%)	32.5	37.0	46.5	55.5
Increase in Sewage B.O.D. (%)	22.4	25.3	32.4	38.2

garbage suspended solids will never be as high as the garbage total solids. Green garbage contains both grit and soluble solids. Grit is removed in the plant grit chambers and many of the soluble solids are absorbed by the sewage and therefore the remainder, or suspended solids, must be less than the garbage total solids. This was clearly demonstrated at Indianapolis, where the total garbage solids and suspended solids were shown to be 350 and 260 lb. per ton of green garbage, respectively. Backmeyer's results (3) at Marion, Indiana for the past three years confirm this latter figure.

The greater the distance from the plant that garbage is ground, the less will be the suspended solids arriving at the plant, due to leaching out of soluble garbage solids by the flowing sewage. Furthermore, it should be remembered that the increase in soluble solids will result in an increase in B.O.D at the plant. The increase in such solids and B.O.D. will not be alarmingly great, however, as Table 2 will show.

Table 2 shows the increase in strength of raw sewage caused by the addition of garbage estimated at 0.5 lb. per capita per day. Varying total solids contents of garbage are given, together with rates of addition in tons per million gallons of sewage. Raw sewage flow is assumed to be 100 gal. per capita per day and suspended solids 0.20 lb. and B.O.D. 0.17 lb. per capita. Calculations from Indianapolis data show that garbage suspended solids equal 74 per cent of the total garbage solids, and B.O.D. equals 58.5 per cent of suspended solids.

This table indicates the need of more information on the total solids content of the green garbage before accurate estimates can be made on increases in sewage strength from garbage additions. The table indicates, however, that if garbage solids and B.O.D. are removed in primary settling to the same degree that sewage solids are removed, the plant unit which will need to be enlarged considerably will be the digester, and secondary processes a smaller amount.

Table 3 shows the increase in strength of raw sewage in p.p.m. and per cent increase due to the addition of garbage of a given total solids content added

TABLE 3.—Increases in Strength of Raw Sewage Due to Addition of Garbage of Constant Total Solids Content Applied at Varying Rates

Garbage (tons/m.g.)	Suspended Solids (p.p.m.)				B.O.D. (p.p.m.)			
	Raw Sewage	Garbage	Total	Increase (%)	Raw Sewage	Garbage	Total	Increase (%)
0	250	0	250	0.0	200	0	200	0.0
1	250	31	281	12.5	200	18	218	9.0
2	250	62	312	25.0	200	36	236	18.0
3	250	93	343	37.5	200	54	254	27.0

to the sewage at varying rates, based upon Indianapolis figures of garbage suspended solids at 260 lb. per ton of green garbage and B.O.D. at 152 lb. per ton. The total solids in garbage is assumed to be 17.5 per cent. (If the total solids of the garbage are higher or lower, the garbage suspended solids and B.O.D. will be in direct proportion.)

This table illustrates how increases from garbage may be calculated. If one knows the strength of the raw sewage, the garbage total solids, and the rate at which garbage is added, he can readily determine the strength of the mixture.

The Effect Upon Primary Treatment at Indianapolis

At Indianapolis, during the grinding test June 3 to December 14, 1935, the raw sewage, including the ground garbage, contained 382 p.p.m. of suspended solids and 273 p.p.m. of B.O.D. Corresponding per capita per day figures were 0.39 and 0.28. During this period the total garbage ground was 17,256 tons and the average addition of garbage to sewage was 2.0 tons per m.g., assuming the garbage to have been added uniformly over each 24 hours. During this period the actual increases in suspended solids and B.O.D. in the raw sewage were 13 and 15 per cent respectively. The increase in strength in laboratory settled sewage to which garbage had been added after 30 minutes of settling was 3 per cent in suspended solids and 11 per cent in B.O.D. These data indicate that garbage solids and B.O.D. are removed more rapidly by primary settling than are sewage constituents. These increases would have been higher had the raw sewage been weaker, or a more normal sewage. Actual increases during the time garbage was ground each day were 27 per cent in suspended solids and 34 per cent in B.O.D. in the raw sewage, and 6.3 per cent in suspended solids and 25 per cent in B.O.D. in laboratory settled sewage. During this time garbage was ground for 10 hours per day and garbage was added to the sewage at a rate of 4.8 tons per m.g. of raw sewage.

Primary Treatment at Findlay, Ohio

The plant at Findlay, Ohio has been in operation since 1933. It was designed by Jones and Henry, Consulting Engineers, of Toledo, Ohio. Designed to serve an ultimate population of 35,000, the original plant consisted of primary treatment with separate sludge digestion and sand drying beds. During 1938, secondary treatment by activated sludge was added, and at the same time a garbage grinder was installed. At the time of the plant additions the digestion capacity was not changed, but one gas engine was added to use digester gas.

Garbage is ground at the plant and introduced into the raw sewage ahead of the detritors and primary tanks. The garbage is ground once or twice a day, usually once on the day shift and once on the night shift. Each grinding operation takes from 15 to 30 minutes. Lime is usually sprinkled on the garbage before grinding, for odor and pH control.

Excess activated sludge is returned to the head of the plant, usually on the early night shift. Supernatant from the digester was returned to the head of the plant until 1940 when, due to its high solids content only 52 per cent was returned. In 1941 only 39 per cent was returned and since that time all the supernatant has been lagooned.

A study of the performance of the primary tanks at this plant is interesting, as this is one place where a comparison can be made with and without garbage. At the time activated sludge treatment was started, garbage was added to the sewage, but this does not appear to have produced unfavorable results except as the excess sludge and

TABLE 4.—Primary Tank Performance at Findlay, Ohio Before Garbage Grinding and Secondary Treatment

Period	Flow (m.g.d.)	Detention (hr.)	Suspended Solids			B.O.D.		
			Raw (p.p.m.)	Effl. (p.p.m.)	Rem. (%)	Raw (p.p.m.)	Effl. (p.p.m.)	Rem. (%)
1933	1.8	4.3	159	78	51.0	152	120	21.2
1934	1.7	4.5	195	95	51.3	192	135	29.7
1935	1.3	5.9	204	91	55.4	172	126	26.8
1936	2.0	3.8	180	82	54.5	179	126	29.6
1937	2.3	3.3	138	70	49.3	132	96	27.3
1938	2.4	3.2	156	72	53.8	174	133	22.6
Average	1.8	4.3	172	81	53.0	167	123	25.4

garbage contributed to the overloading of the digester.

Table 4 is a record of primary tank performance prior to garbage grinding and secondary treatment, while Table 5 gives results afterwards. In Table 5, the raw sewage suspended solids, including garbage, are calculated from waste sludge data plus solids lost in the final effluent. B.O.D. in raw sewage has been calculated on the basis that 1 p.p.m. suspended solids is equivalent to 0.97 p.p.m. of B.O.D. (the 1933 and 1935 average). It has been necessary to use this complicated method of calculation, as the annual figures in the Findlay reports on raw sewage suspended solids and B.O.D. are unreliable, due to an apparent sampling error. It is believed, however, that the raw sewage figures thus arrived at are much nearer the true figures than those in the annual report. Garbage is very difficult material to sample and it is easy to visualize how a few rather large particles of garbage in a raw sewage sample could introduce errors of 100 per cent or more.

TABLE 5.—Primary Tank Performance at Findlay, Ohio After Garbage Grinding and Secondary Treatment

Period	Flow (m.g.d.)	Detention (hr.)	Tons Garbage Per M.G.	Suspended Solids			B.O.D.		
				Raw Sew. and Garb.* (p.p.m.)	Effl. (p.p.m.)	Rem. (%)	Raw Sew. and Garb.** (p.p.m.)	Effl. (p.p.m.)	Rem. (%)
1939	2.4	3.2	2.1	292	103	64.8	284	167	41.2
1940	2.4	3.2	1.1	225	90	60.0	218	139	36.2
1941	2.2	3.5	1.3	208	113	45.7	202	172	14.9
1942	2.3	3.3	1.1	175	90	48.6	170	121	28.8
1943	2.1	3.6	0.8	163	75	54.0	158	125	20.9
1944	2.1	3.6	0.5	184	92	50.0	179	160	10.6
1945	2.0	3.8	0.7	211	98	53.5	205	147	28.3
1939–45 Average	2.2	3.5	1.1	208	94	54.8	202	147	27.2
1942–45 Average	2.1	3.6	0.8	183	88	51.8	178	138	22.5

* Calculated from waste sludge plus solids in final effluent.

** Calculated on basis of 1 p.p.m. of suspended solids = 0.97 p.p.m. of B.O.D. (1933–1938 average).

Table 4 shows that before garbage grinding and secondary treatment, the removals in primary settling for six years, with a 4.3-hr. detention period, averaged 53.0 per cent of suspended solids and 25.4 pe. cent of B.O.D. Table 5 shows that the average removal for seven years since garbage grinding and secondary treatment, with a detention period of 3.5 hrs., was 54.8 per cent of suspended solids and 27.2 per cent of B.O.D. From 1939 to 1941 trouble has been experienced with high solids in the supernatant from the digester and it is believed that this accounts for the high solids and B.O.D. in the primary effluent. Since 1941 all supernatant has been lagooned. Excluding the years 1939–41 from the averages, the period removal is 51.8 per cent for suspended solids and 22.5 per cent for B.O.D. These removals are only slightly lower than those for 1933–1935, and are in line with the lower detention period.

Results in 1944 and 1945 were unsatisfactory due to a lack of operating personnel and, at times, to such a deficiency of digester and lagoon capacities that sludge was allowed to accumulate in the primary tanks until they were, in effect, digesters. During these periods the solids and B.O.D. in the primary effluent were excessively high. The increase in raw sewage solids and B.O.D were 6.2 and 6.2 per cent, respectively, over the 1933–1938 period average when no garbage was added, while increases in the effluent in suspended solids and B.O.D. were 8.7 and 12.2 per cent respectively. The differences are assumed to be from garbage added at a rate of 0.8 tons per m.g. of sewage.

Note further that the averages for 1942 and 1943, when garbage was being added at a rate of 1.0 ton per m.g., showed an increase in the final effluent of 3 p.p.m. of suspended solids, but no increase in B.O.D., over the 1933–1938 period. This was a period when the primary tanks were not receiving a high solids supernatant, as was the case in 1939–41, or bothered by other operating troubles as previously described in 1944 and 1945.

The average of results for these two years shows that garbage suspended solids and B.O.D. are removed more readily by primary settling than are sewage solids alone, and that the ultimate effect on secondary treatment will be almost negligible.

Primary Settling at Marion, Indiana

Marion, Ind. is served by a dual disposal plant where part of the time the garbage has been added directly to the sewage and part time directly to the digesters. Designed by Consoer, Townsend and Quinlan of Chicago to serve a population of 40,000, it is now operating at about 75 per cent of capacity. The plant is of the activated sludge type with separate sludge digestion. A Jeffrey grinder is provided for grinding the green garbage. This plant, like the one at Findlay, Ohio, is subject to quite severe loads at times from canneries and packing houses.

Table 6 gives primary settling results at Marion. The first period (September, 1940 to June, 1941) was without garbage, as was the third period (May, 1943 to January 1, 1946). The second period (June, 1941 to May, 1943) was with garbage added ahead of the primary tanks. Weighted averages for the first and third periods considered together show removals in suspended solids and B.O.D. to be 50.2 and 32.1 per cent, respectively, with a detention period of 1.9 hours. Removals in the second period, with a 2.1-hr. detention and with garbage added at a rate of 0.9 ton per m.g. of sewage, were 62.3 per cent of suspended solids and 42.7 per cent of B.O.D. These differences in removals cannot be accounted for by difference in strength of the raw sewage, and it would appear that during the second period ground garbage had a flocculating effect that helped give greater re-

TABLE 6.—Primary Tank Performance at Marion, Ind.*

Period	Flow (m.g.d.)	Detention (hr.)	Tons Garbage Per M.G.	Suspended Solids (p.p.m.)					B.O.D. (p.p.m.)				
				Raw Sewage	Garbage†	Total	Effl.	Rem. (%)	Raw Sewage	Garbage†	Total	Effl.	Rem. (%)
9–40 to 6–41	2.3	3.1	None	262	0	262	140	46.5	252	0	252	157	38.5
6–41 to 9–41	3.4	2.1	2.0	342	31	373	104	72.0	222	17	240	140	41.3
9–41 to 9–42	3.4	2.1	0.8	299	26	325	132	59.3	240	14	254	152	40.1
9–42 to 5–43	3.7	1.9	0.6	248	20	268	99	63.0	198	11	209	112	46.3
Average	3.5	2.1	0.9	286	25	311	117	62.3	222	14	236	135	42.7
5–43 to 1–44	3.8	1.9	0.0	221	None	221	110	50.1	145	None	145	98	32.5
1944	4.3	1.7	0.0	229	None	229	107	53.2	172	None	172	119	30.7
1945	4.8	1.5	0.0	214	None	214	105	50.8	183	None	183	131	28.4
Average	4.4	1.6	0.0	222	None	222	107	51.9	169	None	169	118	30.2

* From June, 1941 to May 1, 1943 garbage added directly to sewage, but since May 1, 1943 garbage has been added directly to digester.

† Denotes calculated figure: 1 ton of garbage equal to 260 lb. of suspended solids and 152 lb. of B.O.D.

movals than would have otherwise been the case. To be ultra-conservative, it can be said that garbage suspended solids and B.O.D. are removed as readily as are similar constituents in raw sewage. Attention is directed to the slight effect at this plant that garbage addition at a rate of 0.9 tons per m.g. has upon the strength of raw sewage.

Effect of Ground Garbage Upon Activated Sludge Plant Operation

Table 7 gives results of activated sludge plant operation at Indianapolis, Findlay and Marion, with and without garbage. Note that in 1935, at Indianapolis, the removal in B.O.D. in pounds per 1,000 cu. ft. of air was almost exactly the same for the period with garbage as compared with that without garbage.

At Findlay, the average for seven years shows only a slightly lower efficiency in use of air than that at Indianapolis. This was with garbage applied at a rate of 1.1 tons per m.g. of sewage, as against 2.0 tons per m.g. at Indianapolis. The Findlay air efficiencies are quite good, however, considering that these results include for the most part all months of the year, while the Indianapolis results cover only summer and autumn months.

At Marion, disregarding the period when the plant was starting up, the plant efficiency so far as use of air goes, although somewhat lower than at Indianapolis or Findlay, is practically the same whether garbage is present or not. From this it is concluded that garbage solids are oxidized by activated sludge as readily as are sewage solids.

Performance of Digesters With and Without Garbage

Table 8 gives digester operation data at Findlay and Marion. Attention is drawn to the last column, headed "Digester Capacity." Populations are calculated from actual daily pounds of dry solids added to the digesters, divided by 0.2 (the theoretical pounds of solids per person per day). This method of figuring is believed better to show actual loadings than by use of tributary populations, as it takes into account solids from all sources and not from domestic origin only.

At Findlay, the first period covers from 1935 through 1938, when primary sludge only was digested, while the second period covers seven years since primary and secondary sludge and garbage were digested. A comparison of these two periods is very interesting. During the first period the digesters operated very well, but during the second period trouble developed. While the solids in the raw sludge dropped only slightly, the solids in the digested sludge decreased over 50 per cent and a supernatant of high solids developed that caused trouble when returned to the head of the plant. A study of the volatiles shows quite satisfactory digestion. Gas production doubled, but all gas figures are low as only the gas used in the plant is measured. Digester loading doubled and digester capacities dropped from 7.7 to 3.5 cu. ft. per capita. These results

TABLE 7.—Performance of Activated Sludge Plants Handling Garbage

Year	Place	Period	Tons Garbage per M.G.	Aeration Period (hr.)	Applied Air (cu. ft. per gal.)	B.O.D. (p.p.m.)		B.O.D. Removed (Lb. per 1,000 cu. ft. air)	Sludge Index
						In	Out		
1934	Indianapolis	June–Dec.	None	7.2	1.23	228	27	1.34	—
1935	Indianapolis	June–Dec.	2.0	7.0	1.23	231	28	1.35	—
1939	Findlay	Jan.–Dec.	2.1	7.0	1.09	167	15	1.16	—
1940	Findlay	June–Nov.	1.0	7.8	1.00	139	20	1.00	82
1941	Findlay	April–Dec.	1.2	6.7	0.86	172	21	1.46	82
1942	Findlay	Jan.–Dec.	1.2	5.5	0.69	121	21	1.21	151
1943	Findlay	Jan.–Dec.	0.8	4.8	0.63	125	17	1.42	86
1944	Findlay	Jan.–Dec.	0.5	6.2	0.83	160	22	1.39	122
1945	Findlay	Jan.–Nov.	0.7	6.2	0.77	147	22	1.35	126
Average			1.1	6.3	0.84	147	19	1.28	108
1941	Marion	Sept., 1940–June, 1941	0.0	7.3	1.33	157	16	0.89	76
1941	Marion	June–Sept.	1.0	5.2	1.06	140	14	0.99	82
1942	Marion	Sept., 1941–Sept., 1942	0.8	5.1	1.03	152	14	1.11	140
1943	Marion	Sept., 1942–May, 1943	0.6	4.1	0.62	103	9	1.26	40
Average			0.8	4.6	0.90	132	12	1.12	87
1943	Marion	May, 1943–Jan., 1944	None	4.2	0.62	98	9	1.19	68
1944	Marion	Jan.–Dec.	None	4.2	0.77	119	12	1.16	57
1945	Marion	Jan.–Dec.	None	4.0	0.78	131	16	1.22	65
Average				4.1	0.72	116	12	1.19	63

TABLE 8.—Digester Data at Findlay, Ohio and Marion, Ind.—With and Without Garbage.

Place	Remarks	Period	Tons Garbage Per M.G.	Per Cent Solids			Per Cent Volatile Solids			Per Cent Vol. Solids Digested	Thousands Cu. Ft. Gas Per M.G.	Digester Loading (lb. dry solids per cu. ft. per mon.)	Digester Capacity† (cu. ft. per cap.)
				Raw Sludge	Digested Sludge	Super-natant	Raw Sludge	Digested Sludge	Super-natant				
Findlay	Primary treatment only	1935	0	5.1	13.4	—	65.2	47.8	—	68.0	7.0*	0.91	6.8
Findlay	No garbage	1936	0	2.6	10.6	—	65.9	47.8	—	68.5	4.9*	0.68	8.9
Findlay		1937	0	5.4	14.0	—	62.8	43.2	—	62.4	3.9*	0.80	7.5
Findlay		1938	0	4.7	12.5	—	64.2	45.7	—	70.0	4.4*	0.76	8.0
			0	4.5	12.6		64.5	46.1		67.2	5.1*	0.77	7.7
Findlay	Complete treatment	1939	2.1	5.2	4.6	2.6	64.5	47.4	50.0	56.5	9.9*	2.90	2.1
Findlay	plus garbage direct	1940	1.1	4.8	7.3	1.3	70.7	46.5	52.9	63.1	11.0*	1.42	4.3
Findlay	to sewage	1941	1.3	5.0	6.5	1.0	73.1	52.6	59.7	52.5	12.6*	1.33	4.5
Findlay		1942	1.1	4.3	4.5	2.0	73.5	53.4	58.1	61.2	9.4*	1.32	4.6
Findlay		1943	0.8	4.1	4.0	1.7	68.9	58.1	53.8	55.5	6.7*	1.14	5.3
Findlay		1944	0.5	3.4	4.4	1.8	75.9	55.4	59.9	53.8	8.9*	1.21	5.0
Findlay		1945	0.7	3.8	4.1	1.9	75.5	57.0	61.5	55.9	10.3*	1.45	4.2
			1.1	4.4	5.1	1.8	71.7	52.9	56.7	57.1	9.9*	1.54	4.3
Marion	Complete treatment only	Sept., 1940 to June, 1941	None	4.4	6.1	0.8	64.8	41.1	44.5	79.3	25.5	1.72	3.5
Marion	Complete treatment plus garbage direct to sewage	June, 1941 to Sept., 1941	2.0	6.7	6.1	1.1	50.3	39.5	45.7	51.1	18.1	2.91	1.8
Marion		Sept., 1941 to Sept., 1942	0.8	4.9	6.5	0.7	55.5	38.5	47.8	63.2	14.9	2.62	2.3
Marion		Sept., 1942 to May, 1943	0.6	5.4	7.0	0.4	58.3	36.8	41.5	65.3	12.5	2.18	2.8
Average			0.9	5.4	6.4	0.7	55.9	38.1	45.0	62.5	14.4	2.50	2.5
Marion	Complete treatment Garbage direct to	May, 1943 to Jan., 1944	0.9	5.6	7.9	0.3	50.6	34.9	37.3	60.0	10.9	2.13	2.8
Marion	digesters	1944	0.7	5.6	4.8	0.6	54.3	41.0	42.5	50.6	12.2	2.02	2.9
Marion		1945	0.7	5.0	3.8	1.2	59.4	43.6	46.1	49.5	13.5	2.10	2.9
Average			0.8	5.4	5.3	0.7	55.1	40.2	42.3	52.8	12.3	2.08	2.9

* Figures are low as only used gas is measured.
† Population calculated from dry pounds of solids per day to the digesters and per capita solids of 0.20 lb. per day.

clearly show a need for increased digestion capacity to handle the primary, excess activated and garbage solids at Findlay.

The low volatiles in the raw and digested sludges at Marion, as shown in Table 8, are due to a diluting effect by inorganic solids in the lime sludge from the water softening plant, which is present in the raw sludge. In analyzing all sludge samples, oven temperatures are kept at 1,000° to 1,200° F., to keep from volatilizing the CO_2 present in the lime sludge. Otherwise the analyses would indicate abnormally high volatile solids in the sewage sludge. Supt. Backmeyer believes that the volatiles thus measured represent the organic volatile solids only.

A study of the first period at Marion is most interesting, as this period covered nine months of plant operation when primary and excess activated sludge solids were digested without garbage. During this period, while digestion was satisfactory and the gas production high, yet the digesters were overloaded and the supernatant from them was not satisfactory. Note that the loadings were too high and, consequently, the digestion capacity was too low to produce satisfactory results even before garbage was added.

During the second period garbage solids were added as primary tank sludge, since garbage was added to the plant influent, while in the third period the garbage solids were sent directly to the digesters. During the second and third periods garbage amounted to 0.9 and 0.8 of a ton per m.g. of raw sewage, respectively. During these two periods digestion was quite satisfactory, although not as complete as during the first period, but the quality of the supernatant was unsatisfactory. Digestion was least complete in the third period. Gas production per million gallons of sewage was less, but this was due almost entirely to larger sewage flows and lower strength during these periods. Note the tank loadings and digester capacities in these two periods. Since the loadings were higher than those in the first period, where insufficient digestion capacity was evident, it is surprising that the results with these higher loadings were as good as they were.

Cost of Garbage Disposal at Findlay, Ohio

Table 9 shows the average annual operating cost of garbage disposal at Findlay, including all operating costs chargeable to garbage and taking credit for excess garbage gas produced from digestion of garbage, after deducting that required to oxidize the garbage B.O.D. in the primary effluent. The amount of gas from the digestion of garbage is assumed to total 10 cu. ft. per one pound of garbage volatile solids added. This is reasonable, as the average production during garbage grinding was 8.5 cu. ft. per pound of volatile, and it is known that this figure is low as this includes only the used gas and not the total gas. Garbage volatile solids are calculated

TABLE 9.—Cost of Garbage Disposal at Findlay, Ohio

Cost per year of pumping garbage solids to digester	$ 50.00
Cost of operation of grinder, including labor, electric power, and miscellaneous supplies (880 tons per year at $0.36)	317.00
Cost per year of miscellaneous maintenance chargeable to garbage grinding	128.00
Cost per year of disposal of cans, bones, etc. that could not be ground	150.00
Cost per year of removal of digested garbage sludge, estimated at 160 tons at $1.00 per ton	160.00
Total Expense	$755.00
Credit for 1,220,000 cu. ft. of excess garbage gas at $0.315 per 1,000 cu. ft.	385.00
Net Cost	$370.00
Net cost of disposal per ton of green garbage	$ 0.42

from Indianapolis data which showed that one ton of garbage contains 234 lb. of dry volatile solids. The total average gas production per year from 880 tons of garbage is 2,060,000 cu. ft.

During the years 1942 and 1943 the plant operation was not complicated by supernatant disposal, and it should be noted that the percentage removals of B.O.D. were very close to those for the 1933–1939 period without garbage (Tables 4 and 5) and that the final effluents were almost identical. It can be said conservatively that garbage B.O.D. is removed at the same rate as is sewage B.O.D. Since the theoretical garbage B.O.D. in raw sewage in the second period was 19 p.p.m., it may be concluded that 27.2 per cent was removed in the primary tanks, or there was 14 p.p.m. in the effluent. This checks closely with the 15 p.p.m. difference between the settled effluent for the period 1942 and 1943 and that for the period 1933–1939. The B.O.D. in the primary effluent is thus calculated to be 95,000 lb. per year.

Air required at 780 cu. ft. per one pound of B.O.D. removed is 74,000,000 cu. ft. per year. If the gas engines take 1 cu. ft. of gas for each 100 cu. ft. of air compressed, the gas required to compress this amount of air is 740,000 cu. ft., and therefore the excess for other plant uses is 1,220,000 cu. ft. per year. Gas is valued at $0.315 per 1,000 cu. ft., a value equivalent to the cost of purchased electricity for the air compressor at $0.0113 per kw. hr.

Cost of Garbage Disposal at Marion, Indiana

To introduce this analysis it is necessary to explain the method of disposal of the digested sludge now in use. Up to April, 1943, all digested sludge was dewatered on a vacuum filter and then hauled out with trucks and dumped. Since that time, however, all the sludge has been taken out as liquid sludge in tank trucks and applied to nearby farms as liquid fertilizer. Cost of disposal of garbage sludge is by this method.

TABLE 10.—Cost of Garbage Disposal at Marion, Ind. for Period June, 1941 to January 1, 1946

Cost per year of pumping garbage sludge to digesters and grit to grit channels (including power and operating labor)	$ 585.00
Cost per year of grinder operation, including labor, electricity and miscellaneous supplies (4,961 tons at $0.30)	1,490.00
Cost per year of miscellaneous maintenance chargeable to garbage grinding	450.00
Cost per year of disposal of material that cannot be ground	250.00
Cost of disposal of 281 dry tons of garbage sludge at $2.11 per ton	595.00
Total Expense	$3,370.00
Credit for 10,140,000 cu. ft. of garbage gas at $0.30 per 1,000 cu. ft.	3,042.00
Net Cost	$ 338.00
Net cost per ton of garbage	$ 0.07

Garbage gas is calculated for the second and third periods (Table 6) from an assumed figure of 10 cu. ft. per pound of dry volatile garbage solids added to the digesters. This is believed conservative as the average for 1944 and 1945 was 9.2 cu. ft. per pound of volatiles and small scale garbage digestion tests gave a figure of 13.4 cu. ft. per pound. Therefore, the total gas production from June, 1941, to January, 1946, from 4,961 tons of garbage, is 11,600,000 cu. ft. During the second period (Table 6) it may be assumed that 57.3 per cent of the 14 p.p.m. (or 8 p.p.m.) of garbage B.O.D. passed through the primary tanks to be oxidized in the activated sludge plant. The total garbage B.O.D. for this period was 164,000 lb. Air required to oxidize this garbage B.O.D. at 890 cu. ft. per pound of B.O.D. removed is 146,000,000 cu. ft. Digester gas required at 1 cu. ft. of gas for each 100 cu. ft. of air is 1,460,000 cu. ft. Therefore, the excess garbage gas to be used for operating other

plant units is 10,140,000 cu. ft. This gas is valued at $0.30 per 1,000 cu. ft., as it has about 60 per cent of the heating value of purchased gas at $0.50 per 1,000 cu. ft.

Discussion of Costs at Findlay and Marion

The preceding analysis indicates that at Marion, where garbage is ground at the plant and added directly to the digester, the net cost is only $0.07 per ton. If all of the garbage had been added directly to the digesters during the entire period, there would actually have been a credit to be used for other sewage plant expenses.

The net cost of garbage disposal at Findlay appears to be approximately $0.42 per ton. This is due to somewhat higher operating costs and due to the assumptions that garbage B.O.D. is removed in primary settling at the same rate as sewage B.O.D. There is some evidence in the study of results at both Marion and Findlay that this is not true, and that the mixture of garbage and sewage solids settles faster than sewage solids alone. However, in the absence of proof of this, the assumptions made previously must stand. Even if the costs at Findlay are correct, it should be noted that if the garbage had been ground two miles away from the plant, the net cost per ton would have been almost the same as the cost at Marion.

Goshen, New York

The sewage treatment plant at Goshen, N. Y., was designed by Henry W. Taylor, Consulting Engineer, of New York City. Put into operation in 1940, the plant consists of primary settling tank, two heated digesters, drying beds, and a sand filter for secondary treatment in the summer months only. All of the garbage is ground at the plant and sent directly to the primary sludge digestion tank.

Each digester has a capacity of 6,400 cu. ft. and therefore the digester capacity based upon a present population of 3,000 is 4.3 cu. ft. per capita. From May, 1941, to April, 1942, the garbage at this plant averaged 0.51 lb. per capita per day. The minimum month was 67 per cent of the average and the maximum month 160 per cent of the average. Based upon an average flow of sewage of 450,000 g.p.d., the average amount of garbage is 1.6 tons per m.g. Garbage is ground in a Jeffrey grinder and dropped into an ejector, from which it is blown directly to the primary digester. The ejected material contains all of the garbage solids as well as the so-called garbage grit (bottle tops, glass, bones, etc.).

When the sludge is transferred from the primary to the secondary digester, it first passes through a manhole before entering the ejector. Whenever the operator believes it is necessary, he places a wire mesh screen at the point where the primary digester discharge line enters the manhole, and in this manner removes the larger inorganic solids. This is done occasionally and is not a regular routine operation.

Mr. Taylor believes the removal of garbage grit is unnecessary if a blow-off head of at least 10 ft. is provided at the primary digester sludge draw-off line, and if facilities are provided between the two digesters for removal of the coarser inorganic material. He says that up to 1942, during the period he supervised the operation of this plant, he knows of only one stoppage in the draw-off line from the primary digester, and this was easily broken up by a hose line lowered to the bottom of the sludge riser.

He states that digestion is very satisfactory and that the supernatant is a light straw color having a B.O.D. of less than 300 p.p.m. and a total solids content of approximately 2,000 p.p.m. Ninety per cent of the gas produced comes from the primary digester, so that the second tank is relatively quiet for consolidation of the sludge and for decantation of the tank liquor.

Lansing, Michigan

The plant at Lansing, Mich., was designed by Shoecraft, Drury and McNamee of Ann Arbor, Mich. The plant is of the standard activated type with heated digesters for the combined primary, excess activated and garbage solids, with digested sludge dewatered on vacuum filters and then incinerated. Engines are provided to operate on digester gas. The plant was designed to handle an average flow of 9.0 m.g.d. Primary tanks were designed for 1.0 hr. settling, and the activated sludge tanks for 5.75 hrs. and the final tanks for 2.50 hrs. The four digesters have a combined capacity of 294,000 cu. ft., or provide a capacity of 3.7 cu. ft. per capita, based upon a population of 80,000.

The plant was put in operation in 1938 and was so seriously overloaded by 1942 that it was necessary to discontinue conventional activated sludge operation and to resort to plain aeration without return of any sludge to the aerators. The flow is now approximately 14 m.g.d. Plant additions are now being planned by the consulting engineers, based upon an average flow of 20 m.g.d. and a population of 125,000. Digester capacity is to be increased by 1,088,000 cu. ft., making the total 1,382,000 cu. ft. and equivalent approximately to 11.0 cu. ft. per capita. Garbage is estimated at 13,500 lbs. of dry solids per day, which is equivalent to 0.62 lb. of wet garbage per capita per day at 17.5 per cent solids.

In the enlarged plant it is proposed to discharge the ground garbage into two aerated holding pits for separation of the garbage grit before sending this material to the digesters. The original system resulted in some stoppages of sludge lines from the digesters, due to settling out of garbage grit because of low velocities. Installation of larger capacity pumps eliminated most of this trouble, but the new system should eliminate this entirely.

The garbage collection system, including the garbage cans, is owned and operated by the city. Collections are made daily from the business section and at least twice a week from the remainder of the city. When a can is collected a previously cleaned garbage can is left in its place. The filled cans are hauled to the sewage treatment plant where the garbage is dumped on the floor and fed manually to a Jeffrey grinder after picking out the heavier non-organic matter. The ground pulp is discharged into an ejector, from which it is blown directly to the digesters. For supplying and cleaning of cans the city makes an annual charge of $1.50 per family. The cans, after being unloaded at the plant, are put through an automatic machine which thoroughly washes, sterilizes, and dries them.

Table 11 gives interesting data on garbage for a 4-year period. Note that the average for four years shows the garbage solids to be 17.5 per cent, with a volatile content (on a dry basis) of 88.4 per cent, and that the per capita contributions were 0.66 lb. per day of green garbage. The minimum month is 82 per cent of the average month and the maximum is 165 per cent of the average. For the year May, 1944, to May, 1945, the garbage total solids were 57 per cent of the sewage solids removed in the plant, excluding supernatant solids, or 28 per cent of the suspended solids in the raw sewage. The raw sewage suspended solids were 258 p.p.m. while the suspended solids removed in the plant were 127 p.p.m. During this period the garbage ground and ejected to the digesters amounted to 2.0 tons per m.g. of raw sewage.

Table 12 shows digester performance at Lansing. The solids content of the sludge passing to the digester, including not only primary and secondary solids, but garbage and supernatant solids as well, is 9.7 per cent. This is reduced to 7.4 per cent in the digested

TABLE 11.—Data on Garbage Production at Lansing Mich.

Month	1942–1943				1943–1944				1944–1945				1945–1946			
	Wet Garbage				Wet Garbage				Wet Garbage				Wet Garbage			
	1,000 Pounds Per Month	Pounds Per Capita Per Day	Per Cent Solids	Per Cent Volatile	1,000 Pounds Per Month	Pounds Per Capita Per Day	Per Cent Solids	Per Cent Volatile	1,000 Pounds Per Month	Pounds Per Capita Per Day	Per Cent Solids	Per Cent Volatile	1,000 Pounds Per Month	Pounds Per Capita Per Day	Per Cent Solids	Per Cent Volatile
May	1390	0.56	14.7	91.0	1280	0.51	17.8	88.6	1590	0.63	18.0	88.2	1600	0.63	21.6	88.4
June	1480	0.62	16.1	89.0	1500	0.61	13.2	86.3	1610	0.65	14.8	75.8	1550	0.63	20.7	85.9
July	1910	0.77	16.5	89.7	1470	0.58	16.2	91.5	1550	0.61	16.9	87.4	1540	0.61	17.2	80.9
August	2190	0.88	14.3	91.4	1670	0.66	12.3	87.5	2020	0.80	17.3	86.5	1730	0.68	19.1	84.9
September	2740	1.14	12.9	90.2	2050	0.87	12.8	87.5	2260	0.91	16.2	89.9	2260	0.91	18.6	89.5
October	1810	0.70	16.0	87.7	2340	0.92	8.5	89.7	1820	0.72	15.3	93.1	2010	0.79	16.8	90.9
November	1450	0.76	15.5	92.4	1400	0.57	17.3	90.2	1610	0.65	18.4	88.9	1560	0.63	18.8	86.7
December	1680	0.66	15.5	92.4	1470	0.57	22.8	85.0	1510	0.59	20.5	84.5	1580	0.62	18.1	90.8
January	1440	0.57	17.8	94.0	1490	0.59	19.9	89.4	1540	0.62	20.5	86.2	1690	0.67	18.0	91.0
February	1320	0.57	20.3	90.2	1390	0.58	18.6	89.9	2240	0.60	16.3	91.5	1530	0.66	19.2	84.0
March	1520	0.59	17.9	91.5	1520	0.60	22.8	84.5	1590	0.63	18.6	86.5	1580	0.62	19.8	88.3
April	1380	0.56	15.4	93.4	1400	0.57	20.3	84.8	1470	0.60	20.6	87.5	1680	0.66	21.3	88.9
Average	1670	0.68	16.1	91.1	1530	0.61	16.9	87.9	1650	0.66	17.8	87.2	1690	0.68	19.1	87.5

TABLE 12.—Digester Performance at Lansing, Mich.

Month	Tons Garbage Per M.G.	Per Cent Solids			Per Cent Volatile Solids			Per Cent Vol. Solids Digested	Digester Loading (dry lb. per cu. ft. per mon.)		Digester Capacity (cu. ft. per capita)	1,000 Cu. Ft. of Gas Per M.G.
		Raw Sludge*	Digested Sludge	Supernatant	Raw Sludge*	Digested Sludge	Supernatant		Sludge Solids†	Vol. Solids†		
1944												
May	1.9	11.1	8.4	8.2	70.4	64.0	66.0	35.4	6.1	4.9	1.1	19.0
June	1.9	10.6	8.7	8.4	69.3	61.8	66.4	30.0	5.9	4.4	1.4	17.6
July	1.8	9.1	8.4	8.1	73.7	57.6	69.8	19.7	3.9	2.9	1.6	15.4
August	2.3	9.5	8.7	6.8	76.1	53.8	78.9	42.3	5.2	3.9	1.6	17.1
September	2.9	8.7	7.0	6.3	76.5	55.9	76.1	36.2	4.8	2.6	1.3	19.1
October	2.1	7.8	6.7	5.4	77.0	56.9	72.4	34.5	4.7	3.6	1.3	16.6
November	2.0	8.7	5.0		77.5	60.3			5.7	4.5	1.1	18.3
December	1.7	9.1	5.9	5.2	74.8	60.3	70.6	45.8	6.5	4.9	1.0	17.5
1945												
January	1.7	10.5	6.4	6.4	70 1	59.6	65.0	44.5	9.1	6.4	0.7	17.2
February	1.7	10.2	7.2	6.7	68.5	60.7	63.3	38.7	7.6	5.2	0.7	17.3
March												
April	2.0	11.5	9.4	8.7	69.0	61.9	64.2	30.1	8.8	6.1	0.7	21.8
Average	2.0	9.7	7.4	7.0	73.0	59.3	69.3	42.7	6.2	4.5	1.1	17.9

* Includes garbage.

† Includes supernatant solids which were returned ahead of plant and settled in primary tanks.

sludge and 7.0 per cent in the supernatant. This information, together with the high gas production, indicates the tanks are so agitated that the digested sludge does not have an opportunity to consolidate and leave a relatively clear supernatant zone.

An examination of the volatile and digester loadings indicates insufficient digester capacity. Population for calculating digester capacity in cubic feet per capita has been made by including the total weight of dry solids per day from all sources (primary, secondary, garbage and supernatant) passing to the digesters, divided by 0.2 (pounds of dry solids per capita per day). While this method may be questioned, it is believed that it best indicates capacities now existing under present operating conditions. The volatiles digested, while not satisfactory, show surprisingly good results under present conditions. The above shows clearly that combined primary, secondary, and garbage solids, added at a rate of 2.0 tons per m.g. of raw sewage treated, can be digested satisfactorily, but that increased digestion space is urgently needed.

Summary

In summarizing, it is emphasized that the foregoing analysis covers only the physical effects of ground garbage upon the various plant units, together with an analysis of cost of this method of garbage disposal. Operation costs only are given, and interest and depreciation charges are not included. It is recognized that various plant units will have to be increased in size to take care of the additional garbage load, and the added first cost of these should be evaluated in comparing this method of garbage disposal with other means of disposal, so as to arrive at the lowest annual capitalized cost. Such an analysis is beyond the scope of this paper, but such rough calculations as have been made indicate that garbage digestion and disposal at the sewage

treatment plant is probably the most economical.

Any city contemplating dual disposal should insist on green garbage only being sent to the garbage grinding station. This will avoid the costly sorting and disposal of the non-grindable material. Such wastes must be disposed of in the same manner as are ashes, trash, and other rubbish.

While the trend is toward an increasing number of home garbage grinder installations, a recent study made in the East Bay area at San Francisco, Calif., indicates that only 30 per cent will be installed by 1970 and 70 per cent by the year 2000. If this is true, the effect of food wastes from this source will be of minor importance at sewage works for the next 25 years. Since the trend is as indicated above, however, designing engineers should recognize it and design their plants accordingly.

The results of primary settling at Findlay, Ohio, and Marion, Indiana, indicate that garbage solids and B.O.D. are removed as readily as are similar sewage constituents. To ensure no more solids and B.O.D. passing to the secondary processes than would have been the case without the added garbage, it will be necessary to provide some additional detention time in the primary tanks or precede these with short period flocculation without the addition of coagulants.

It is indicated that garbage B.O.D. does not retard the oxidizing ability of activated sludge and it is believed that this will hold true for either high or low rate trickling filters.

All of the plants studied show that garbage solids are as readily digested as are sewage solids, and that gas production is increased in direct proportion to the amount of garbage volatile solids added, but that the resulting sludge will be of somewhat lower solids content. The results at Goshen indicate that about 3 cu. ft. per capita of digester capacity is ample, for garbage added at a rate of 2 tons per m.g. of sewage. This capacity is in excess of digester capacities normally provided for the digestion of sewage solids. These studies show that at least two digestion tanks should be provided even in small plants, so that there is one relatively quiet tank for maximum consolidation of the sludge and for removal of a satisfactory supernatant. Although these studies show overloaded digesters at all plants except Goshen, there is nothing to indicate that more digester space would not solve the problem at all plants.

In spite of the operating troubles at some of the plants, caused by inadequate digesters, one cannot but be impressed with the relative ease and simplicity with which garbage is now handled, and with the lack of complicated machinery that handling of the garbage involves.

Also, one is impressed with the spirit of the men in charge of these plants. They are sure that this method is the best and most economical for their plants. These pioneers have done a fine job, against many operating difficulties, and they are to be commended for proving that dual disposal is feasible and economical. With this knowledge it is possible to lighten the load of future operators and provide them with better plant facilities.

Grinding stations equipped as outlined earlier in this paper should go far toward satisfactorily handling the garbage grinding and grit removal operations, while provision of adequate digester capacity should solve that phase of the problem.

Since the records prove the feasibility and economy of dual disposal, it seems to the writer that all concerned —public officials, designing engineers, and plant superintendents—rather than discouraging garbage disposal by this means, should advocate it and encourage its adoption. For the public official it means an entirely sanitary and satisfactory solution of this

troublesome problem. For the designing engineer it means a bigger and better plant to design. For the plant superintendent it means an additional responsibility with increased problems, but along with this should go increased remuneration.

Conclusions

The following conclusions and recommendations are made where garbage is added to the sewage at an average daily rate of 2 tons per m.g. of sewage.

1. Facilities should be provided for removal of garbage grit before this material is sent to the digesters.

2. When garbage is added to the raw sewage, the increase in suspended solids will be approximately 25 to 35 per cent, and in B.O.D. 18 to 26 per cent, depending upon the solids in the raw garbage.

3. The increase in strength of primary settled sewage after 2.0 hours settling will be approximately 10 to 14 per cent in suspended solids and 11 to 16 per cent in B.O.D.

4. Garbage matter is oxidized by activated sludge and probably by all secondary processes as efficiently as is sewage material; therefore, increased plant secondary units must be based upon the increased garbage load in the primary effluent.

5. For digestion of primary solids and garbage, 5 cu. ft. per capita of digester capacity is needed, while the capacity for primary and secondary sewage solids, plus garbage, should be 9 cu. ft.

6. The most economical means of dual disposal appears to be by direct addition of garbage to the digesters, unless central grinding stations are used.

7. The cost of disposal of garbage at the sewage plant will be between $0.10 and $0.50 per ton.

Acknowledgments

The writer expresses appreciation to Ben. H. Barton, Chief Operator at Findlay, Ohio; David P. Backmeyer, Superintendent of the sewage works at Marion, Ind.; S. D. Porter of the firm of Shoecraft, Drury and McNamee of Ann Arbor, Mich.; and to Henry Taylor, consulting engineer of New York City, for supplying data and for offering other helpful suggestions and criticisms.

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GROUND GARBAGE—ITS EFFECT ON THE SEWER SYSTEM AND SEWAGE TREATMENT PLANT. A DISCUSSION

By Ben H. Barton

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The dearth of reliable data upon what is called "dual disposal," meaning the treatment of ground garbage solids and liquors as sewage, makes Mr. Tolman's paper a valuable contribution. His early experimentation and plant scale experience in the treatment of garbage with sewage at the Indianapolis plant yielded data that have been corroborated in the more recent installations. The writer believes that he has established certain firm standards that may be used as a basis for design computations.

In 1941, speaking informally before the Michigan Sewage Works Association, the writer gave the opinion that "Digester capacity in a complete treatment plant where garbage is treated with sewage solids should start at ten cubic feet per capita." Experience at Findlay since that time has revealed no reason to modify that contention to any considerable degree. The struggle to handle increasing loads with the capacity reported by Mr. Tolman is continued in the hope that stage digestion may some day bring the long awaited relief.

Mr. Tolman's recommendation of 9 cu. ft. per capita is only slightly less than the minimum capacity suggested by the writer. It is understood that extensions to the Lansing, Mich. plant will raise the digestion capacity to 11 cu. ft. per capita. The consultants who are designing improvements to the Findlay plant intend to triple the present digestion capacity, irrespective of the outcome of plans to operate a proposed cannery, which would impose an added load. This trend toward more liberal capacities in dual disposal plants is to be highly commended.

Whatever physical capacities are established for plant design they should in the writer's opinion, be based upon the volatile solids—the organic load that is prone to create nuisance if it is not stabilized. Garbage should be definitely limited to "food wastes of organic nature" from plate scrapings and food preparation. Commercial food wastes should be the problem of its producer. This means that the municipality contemplating dual disposal should accept the domestic garbage of organic nature only, legislating against paper and other extraneous matter which will not create an obvious nuisance during its natural decomposition. The tremendous overload arising from green corn husks in roasting-ear season is a difficult problem in garbage grinding, but corn husks create no nuisance when dried and burned or used as compost or silage. Peach and other fruit pits are in the same category. It is almost impossible to grind feathers.

Experience with the Jeffrey garbage grinder at Findlay has been entirely satisfactory, and only one replacement of hammers has been necessary in 8 years. Knives have been used to advantage in the corn husk season.

The odor nuisance which develops even during short storage periods makes it difficult to level out the garbage loading peaks. Where the collection is under the control of sewage works personnel, dispatching of trucks could alleviate conditions by eliminating the need for appreciable storage. Good housekeeping around a grinding station will go far to reduce odor nuisance, which will become cumulative. Periodic applications of dilute hypochlorite will deodorize the decks. Once

the garbage is ground, whether into the sewage stream or enroute to digestion units, there is no perceptible odor from the garbage.

Detritus matter requires comprehensive consideration regardless of where the ground garbage is applied at the sewage treatment plant. Pending construction of needed additions at the Findlay plant a modification of the pneumatic detritor ahead of the regular detritor is favored if ground garbage is induced into the sewage stream ahead of the plant. The ultimate plan is to introduce the garbage at sludge concentration units where the ground garbage slurry will be mixed with the sewage sludge for conditioning before discharge to digestion units. This conditioning could include concentration, neutralization, preheating and, of prime importance, removal of extraneous matter. Any ground garbage received in the sewage flow from either remote grinding stations or home grinding units would be included in the sewage sludge. Thus all garbage and sludge would receive precisely the same treatment as sewage sludge alone, Nothing further remains to prepare a sewage treatment plant for dual disposal beyond supplying the capacities that Mr. Tolman very ably sets forth in his paper.

A note of warning is in order. Mr. Tolman's conclusions are predicated upon the addition of garbage at the rate of 2 tons per m.g. of sewage, the normal expectancy. Findlay experience has been that 4 tons of garbage per m.g. of sewage is the saturation point for activated sludge, if successful operation is to be maintained without difficulty. Excessive garbage loading rates will upset an activated sludge plant just as will an excessive solids and B.O.D. loading. This can happen when the operators shove all received garbage through the plant during the daytime to get rid of it, but if the garbage loading is added in a sensible and orderly manner and the rate of application kept within reason, no trouble will ensue. Six tons of garbage per million gallons of sewage is guaranteed to upset activated sludge that has not been fortified with an excess of mixed liquor suspended solids in prime condition.

The Findlay data set forth by Mr. Tolman resulted from expediency and were not according to the preconceived notion of the proper way to handle garbage. The recently acute manpower shortage necessitated disregard of electric power demand limitations, and made it necessary to grind garbage whenever enough accumulated to justify starting the grinder. This resulted in two noticeable improvements: (1) the raw sewage samples became more representative, and (2) the plant load curve smoothed out during the daytime. While this method of handling garbage has not been in effect long enough for evaluation, it is noticeable that operation results are better when shock loading is minimized. The power costs are not unduly high.

Mr. Tolman's data show the Findlay cost of disposal of material that can not be ground to be three times the Marion, Ind. costs (Tables 9 and 10). This is due to personnel organization; whereas the Marion garbage is municipally collected and the Findlay garbage is collected by private haulers. Regulation would reduce this difference to the vanishing point.

It seems desirable to neutralize excessive garbage acids. This is done by applying 40-mesh quicklime at the grinder. Care must be taken to avoid an overdose that might slow digestion over a long period of lime dosage. Forty-mesh quicklime is used because it is readily available at a low price in the form of screen tailings from the preparation of pebble lime. A local industrial alkaline waste complicates the lime dosage rate to a point where excessive alkalinity results in turbidity in the final tank. Attempts to out-

guess the alkaline waste are only fairly successful, but an alkaline backlog is maintained in the secondary process to keep an occasional milk waste from causing too much trouble.

While the effluent turbidity is not welcome, it is not reflected in either suspended solids or B.O.D. values. It is believed that activated sludge can become inured to either acid or alkaline conditions provided they are constant, but an upset is certain with any abrupt change in pH value. No instance is known where dual disposal is practiced in a biological filter plant, but it is assumed that it would be desirable to maintain a uniform pH value in the sewage applied even to these rugged units.

Dual disposal is a most effective means of garbage disposal. The cost should not approach the sum of the costs of separate disposal when both are effective and total expenses are accurately known. Since garbage will eventually and inevitably be treated with sewage the problem should be approached subjectively to provide adequate structures rather than makeshifts. The only actual requisite is adequate capacity—in sewers, treatment plants, operation and administration.

Stream Pollution

PROTECTION OF UNDERGROUND WATER FROM SEWAGE AND INDUSTRIAL WASTES *

By Arthur Pickett

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In Southern California, and particularly in the metropolitan area of Los Angeles County, some very serious water pollution problems have been caused by the improper disposal of sewage and industrial wastes. Due to the rapid development which is taking place throughout the area at present, it has been necessary to take action to protect these water supplies, upon which our very existence as a metropolitan area depends.

In all essential respects these problems are identical with those of other communities throughout California, and for that matter the entire United States. Consequently, the procedure and plan for corrective action may be of interest to those affected by similar problems.

Description of Region

Topographically, the 4,000 sq. mi. which comprise Los Angeles County are divided into three parts. About a third of the area is an inland valley. This is not considered to be a desert area as the climate is generally quite pleasant, and much of the land is being developed for farming, although the rainfall averages only 3 to 4 in. per year.

Another third of the county is mountainous with peaks ranging up to 10,000 ft. above sea level. Rainfall in this area is quite heavy and varies according to location and elevation. In the higher ranges, the average reaches 30 to 36 in. annually.

The final third of the county is a semi-arid coastal plain which rises gradually from the Pacific Ocean to elevations of about 1,000 feet. Rainfall in this area also varies according to elevation and location, with averages of from 12 to 14 in. annually.

Metropolitan development of the county has been confined almost entirely to the coastal plain. At the present time, more than 3,600,000 persons, and literally thousands of industries of every description are located on this plain. There are 44 cities with a combined population of almost 3,000,000, and in addition, there are about 100 unincorporated communities with a combined population of more than 600,000.

Development of the area is going forward at a phenomenal rate in spite of material shortages and handicaps of almost every description. This development is expected by many to make Los Angeles the largest metropolitan area in the world within a very short time. Adequate natural resources are available for such development if they are properly protected and conserved. The most important of these is water, which is available from three sources.

Water Supply

First of all, there is the natural supply. More than 500 water companies furnish water for domestic and industrial use of the metropolitan area from wells, water tunnels, reservoirs, nat-

*Presented before 1946 Annual Convention of the California Sewage Works Association, Monterey, California, June 11, 1946.

ural springs, and streams. In addition, thousands of industries, ranchers and farmers have their own supply, obtained in most cases from wells drilled into the underground basins.

To help conserve these natural water resources, as well as to provide needed protection against floods, the Los Angeles County Flood Control District was formed in 1919. The work of this district has been particularly effective. Dams and reservoirs have been built at a cost of $32,000,000, which have a storage capacity of 88,000 acre-feet. These dams and reservoirs, together with appurtenant spreading works, are functioning so effectively that virtually all runoff from the mountains and foothill area is now diverted into the underground storage basins of the coastal plain.

To augment the natural supply, two great aqueducts have been constructed. The Owens River Aqueduct, completed by the city of Los Angeles in 1913, has a capacity of 475 c.f.s. The Colorado River Aqueduct, completed by the Metropolitan Water District in 1939, has a present capacity of 510 c.f.s., which can be readily expanded to supply 1,500 c.f.s., when the need develops.

Los Angeles is located in the semi-arid region where dry cycles or periods of less than average rainfall frequently extend over several years. During these periods the natural water supply is generally inadequate to meet demands, and large reserve storage facilities are essential. Such storage is provided in vast natural underground basins or reservoirs located directly beneath the cities and communities of the coastal plain.

While the geology of these reservoirs is quite complicated, they are essentially prehistoric lakes and valleys which have been filled with sand and gravel, clay and earth, washed down from adjacent mountains. As a result of many years of research by the State Division of Water Resources, the County Flood Control District, and other agencies, accurate information is available regarding locations and characteristics of these great storage basins.

Figure 1 is a map prepared by the State Division of Water Resources, which shows the boundaries of these basins. No one knows exactly the water storage capacity which they represent, as water-bearing gravels extend to depths of from a few hundred feet to as much as 1,000 or 1,500 ft. below the surface. The state has made estimates, however, which reveal that a total of 3,689,000 acre-ft. of water are stored in the first 100 ft. of water-bearing gravels of those basins located within Los Angeles County.

Comparative analysis will better illustrate the important part this tremendous volume of water will play in future development of the metropolitan area. To supply 3,689,000 acre-ft., would require the entire flow from both the Owens River and the Colorado River aqueducts for a period of four years and nine months, and the construction of dams providing 40 times the storage capacity of all flood control reservoirs which have so far been built in the county.

Another comparison can be secured on a cost basis. Certain local water companies are buying excess water from adjacent communities in order to meet their requirements during dry years. For such water, they must pay $30 per acre-ft., over and above the cost of pumping or treatment required. On such a basis, the water stored in the upper 100 ft. of these natural reservoirs has a potential value of more than $110,000,000.

If such assets were available in the form of money, they would be deposited in banks, every reasonable type of protection would be provided, and strict regulation and control would be maintained over deposits and withdrawals. This is not true, however, with regard to discharges of sewage

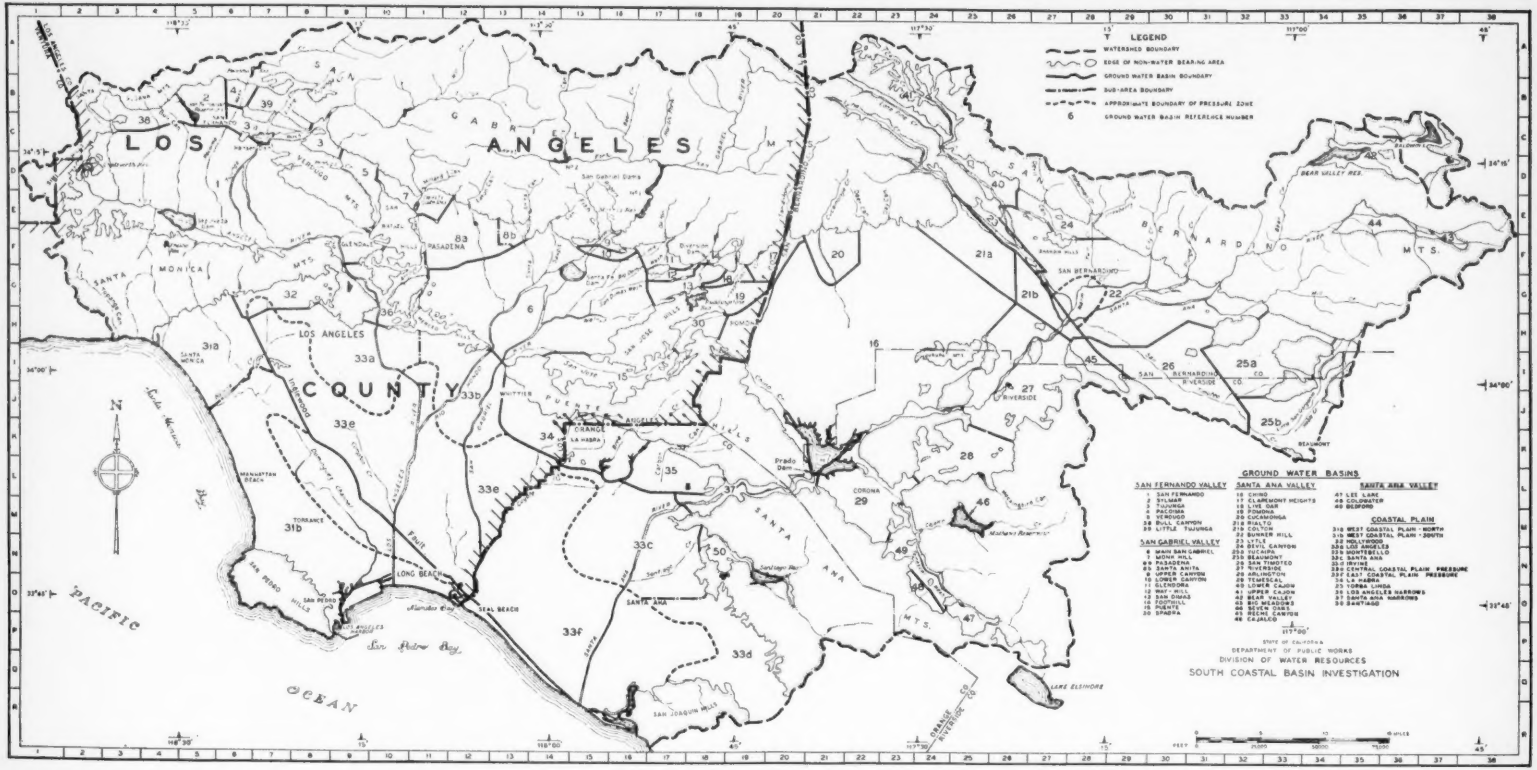

FIGURE 1.—Map of Los Angeles and vicinity showing underground water storage areas. By courtesy of the California State Division of Water Resources.

and industrial wastes into these great water storage reservoirs which lie directly beneath this metropolitan area.

Wastes Disposal

Many communities and two cities of Los Angeles County are unsewered. Liquid wastes from hundreds of thousands of homes, and from thousands of industries, are discharged directly into cesspools, septic tanks, and similar facilities. In some cases, the effluent from these facilities passes through several hundred feet of sand and gravel before reaching the waters of the underground reservoirs. In such areas the only noticeable effect upon the water has been a gradual increase in the presence of salts, metallic ions, and acid radicals.

In other cases, however, cesspools discharge directly into the water of the underground basins, and dilution is the only safeguard against pollution and menace to the public health. Most cities are provided with sewer systems, but no city or community in the area is 100 per cent sewered. Sewer systems are, however, being extended as rapidly as possible. The present coverage has been indicated rather clearly in Figure 2.

FIGURE 2.—Map of Los Angeles County showing districts having access to sewer systems with ocean disposal facilities.

As you will see from examination of this map, Los Angeles and a number of adjacent cities and communities are sewered through the Los Angeles city system and treatment plant, which has an outfall to the Pacific Ocean at Hyperion. This system is heavily overloaded, particularly during the winter months. For this reason, and also to correct beach pollution, and to provide capacity for large unsewered sections of the city, a new treatment plant and relief sewers are being designed. Construction of these facilities is expected to cost approximately $30,000,000.

Most of the remaining cities and communities of the coastal plain are now served or will be served in the near future by facilities of the Los Angeles County Sanitation District. Existing facilities of this great system are more than adequate for present demands and will be expanded in the future to take care of new developments.

Within the past few months, several new districts have been formed in the eastern portion of the county, and have voted bonds for the construction of trunk sewers and purchase of outfall privileges. These districts include Nos. 3, 15, 16, and 17.

The communities affected are: Long Beach, Lakewood Village, Bellflower, Rosemead, Garvey, Puente, Baldwin Park, Arcadia, San Marino, Alhambra, South Pasadena, Pasadena, Altadena, Sierra Madre, and Monrovia. For construction of the trunk sewer and purchase of outfall privileges, $10,529,000 in bonds were voted.

In addition, local sewers will have to be constructed in most of the unincorporated communities, and in some of the cities of these new districts. Accurate figures are not available, but it is estimated that 1,000 miles of local sewers will be required to serve the unincorporated communities in the various sanitation districts.

This estimate is based upon the fact that the County Engineer is now operating about 700 miles of sewers in 50 Sewer Maintenance Districts which serve 225,000 people, and there are at least 350,000 people in the remaining unsewered communities. At $20,000 per mile, these local sewers will cost at least $20,000,000. As the unincorporated area is developing quite rapidly, this total will have to be materially increased and perhaps doubled before the construction program is completed.

Sewage and industrial wastes collected by the outfall sewers of the sanitation districts are carried to a joint disposal plant near Lomita. Treatment consists of primary sedimentation and sludge digestion. Sludge is sold for fertilizer. Gas collected from the digesters is used to operate the plant and to pump the effluent into the ocean.

For this purpose, a tunnel has been constructed under the San Pedro Hills. This tunnel connects with a subterranean ocean outfall adjacent to White's Point. Through this outfall, the sewage is carried about 1 mile off shore to a point where the Pacific Ocean is quite deep, and prevailing currents carry the effluent away from the rocky coast line. By use of diffusers, the effluent is quickly dispersed and purified by action of the sea water.

Remaining cities of the county which have their own separate treatment plants, and which will not tie into the sanitation district or the Los Angeles city system, are San Pedro and Wilmington, Whittier, Azusa, Covina, La Verne, Claremont, and Pomona. When the present construction program is completed, the only cities of the coastal plain which will not be sewered are West Covina and Glendora.

Present Pollution Problem

Unfortunately, existing sewer systems with ocean disposal have not eliminated prevailing water pollution problems for three reasons. First of all, many communities and industries are so located that connection to the sewers is not yet possible.

Secondly, in years past it was the general policy throughout the area, to protect the sewer systems rather than the underground water supplies by prohibiting discharge into the sewers of any industrial wastes which might damage the sewers, increase cost of maintenance and operation, or affect operation of the treatment plants. In numerous cases, industries which should have pretreated their wastes before discharge into the sewers have simply put down cesspools or leaching pits to get rid of the objectionable wastes, and no one has considered the resulting effect upon water supplies. Many serious cases of pollution have resulted, principally from industries having chemical wastes, such as strong acids or alkalis.

A third pollution problem has developed from the honest desire of public officials to conserve and reuse water, especially from industrial plants. Where the quantity of industrial waste is great and the capacity of the sewer system is limited, it is mandatory to follow this practice. In many cases, this can safely be done, for almost all types of industries have a certain amount of water from cooling towers, washing operations and similar processes which is virtually uncontaminated. In most cases, however, it is difficult to separate this water from the remaining wastes of the plant.

For example, many food processing plants use large quantities of water in washing vegetables and fruits as they come from the field. In some cases, these washing operations employ only pure water. In other cases, soda ash or borax is used. Such plants frequently have cooling water from blanching operations or waste water from skinning and pitting operations.

To the plant manager and to public officials, much of this water may appear to be virtually uncontaminated. Where disposal facilities are carefully operated, this may be the case. Frequently, however, inspection is relaxed, operation grows careless, and the wastes discharged from the plant may develop a B.O.D., three times as great as that of domestic sewage. Discharge of this material onto the land can be quite serious.

Similar conditions may arise at paper mills, refrigerating plants, metal processing plants, or at any plant where large quantities of liquid wastes are involved. The most serious problems, however, have developed with the chemical plants manufacturing plastics, hormones, weed killers, and similar products.

The "Montebello Incident"

One such plant has provided an illustration of chemical pollution which is without parallel. This plant caused the so-called "Montebello Incident" where 11 water wells serving 25,000 people were put out of commission by the industrial wastes from a single small plant located 15 miles away.

This plant was engaged in the manufacture of a weed killer and the quantity of its wastes was relatively small, consisting only of water used to wash down the walls and floors of the plant, and to clean out the containers in which the weed killer was prepared. Within three days after the plant started operation, the first well was affected. Within 17 days all of the 11 wells were out of operation, some of them permanently. Although the plant was shut down almost a year ago after less than 30 days operation, water in the area must still be treated with chlorine dioxide before it can be used for domestic purposes.

Fortunately, this pollution was quickly discovered. Had is occurred during a period of receding water in the San Gabriel Basin, it is quite possible that the entire area would have been affected. One ounce of the responsible chemical is sufficient to destroy 2,500,000 gal. of water for domestic use, solely because of its toxic effect and the medicinal odor which it imparts.

One would think that such cases of pollution would be rare. Actually, however, during the past six months, plans for construction of five large new industrial plants have required material revision in order to prevent similar pollution in various sections of the county. Two of these plants planned to manufacture phenolic resins, and to discharge their wastes into adjacent stream beds. Two were large plants having processes using hexavalent chromic acids. The owners of these plants planned to dump their wastes into adjacent river channels directly above large underground water storage basins.

Another case involved a plant which will have 1,500 employees and will engage in the manufacture of a variety of products, including detergents. All of the wastes from this plant, both domestic and industrial, were to be discharged into cesspools in an area where the depth to well water is less than 50 feet.

Experience in the handling of many such cases has demonstrated the need to establish certain simple policies and procedures essential to the protection of water supplies, prevention of nuisance, and menace to the public health and safety.

Regulatory Action

First of all, adequate laws and regulations must be provided to govern the disposal of wastes which cannot or will not be discharged into the sewer system. With regard to domestic wastes, ample protection exists in provisions of the State Health and Safety Code, the Subdivision Map Act, and various local ordinances and regulations. Fortunately, the County Board of Supervisors established a policy several years ago requiring that sewers be installed in new subdivisions whenever required to meet provisions of the state laws or county ordinances.

In existing subdivisions, property owners do not wish to live where conditions are insanitary, and support action to correct such conditions. Cesspools and septic tanks do not operate satisfactorily in a heavily built-up metropolitan area, regardless of the character of the soil. Consequently, property owners sooner or later demand relief through the construction of local sewers. Such demands develop most quickly where the underground water tables are high and the health menace is consequently greatest.

With regard to industrial waste disposal, however, the problem is somewhat different. Chemical pollution can do its damage so quickly that preventive legislation and control are essential. The problem is fundamentally local or regional in character. Because of the thousands of small industries involved, it would be difficult, if not impossible, for the state health department to take over, under provisions of the state law which requires permits in all such cases. Because of the 44 cities, as well as other governmental agencies affected, it is also difficult to obtain uniformity of action at the local level.

As the first step required to meet these problems, amendments to a county ordinance were drafted for regulating waste disposal from industrial plants. These amendments have recently been adopted by the Board of Supervisors, for control of industries in the unincorporated areas of the county. Under the Joint Powers Act, other cities and agencies having similar difficulties can adopt similar legislation and work with the county in solving common problems.

The preparation of this ordinance has been a very difficult job in which many men have taken an active part during the past year. Among those interested were water company officials, representatives of industry, property owners, and the Los Angeles Chamber of Commerce, as well as the various county departments and other governmental agencies which would be affected in some manner by the new legislation.

The multiplicity of ideas and differences of opinion in each of these several groups was amazing. Many water company officials believed that all industrial waste should be discharged into the ocean after treatment. Some of this group believed that reclamation should be practiced and that all waste should be discharged onto the land after treatment. They felt that such treatment should produce an effluent meeting all of the standards of the fresh water delivered by the water company to the plant.

Some of the industrial group believed that they should be allowed to dispose of their wastes in any manner which they choose. This is especially true of the small plant owners where proper disposal would cost money, or would require them to employ technical experts.

Fortunately, a large majority of the interested industrialists are reasonable men who have established their homes as well as their industries in this area. These men realize that protection of the water supplies and prevention of public nuisance or menace to public safety are of primary importance, and they have supported the new legislation.

The Los Angeles Chamber of Commerce, and particularly its Water Pollution Committee, have also participated actively in preparation of the new legislation. This group took the original draft of the proposed ordinance as prepared by the County Counsel, with the assistance of a committee of technical men from the various county departments, and distributed it among representative industries, water companies, and members of the chamber.

Numerous meetings were held with various committees, as well as representatives of special groups affected, in order to remove objectionable features and to secure clarity and effectiveness. In all, five revised drafts were prepared and distributed by the chamber before it was presented to the Board of Supervisors for adoption.

Fundamentally, this ordinance is concerned with the disposal of sewage and industrial waste from industrial plants in a manner which will not create a nuisance, endanger the public health or safety, or pollute the water supplies in unincorporated areas of Los Angeles County. This must be done in a manner which will attract industry to the area, rather than to drive it elsewhere.

To do this, provision is made for three contacts between county officials and industrial plant owners and operators.

First of all, if a new industry plans to locate in the area, provision is made for consultation with plant officials to advise them of waste disposal problems and requirements. Secondly, when application is made for construction of an industrial plant, the County Engineer must inspect the plans, consult the Health Officer and other departments and agencies if necessary, and certify to the Building Department as to waste disposal requirements. This certificate must be included in the approved building plans and, consequently, the builder knows in advance what provision he must make for disposal of wastes.

Finally, after the building is complete, with waste disposal facilities installed and in operation, provision is made for periodic maintenance inspections by the County Health Officer and the County Engineer. Such inspections are essential if these facilities are to be properly maintained, particularly in the smaller plants.

While adequate provision is made for enforcement of the ordinance, experience has shown that almost all plant operators will cooperate willingly if they understand what is wanted and why it is necessary. For this reason, emphasis has been placed on the need for educational work and for cooperative effort. Provision has

also been made for joint action between representatives of industry, water companies, public officials, and property owners in the establishment of standards for disposal of wastes.

Pollution cannot be prevented simply by enacting new legislation, either at the local, state or national levels. Legislation must be backed up with adequate technical personnel to carry out its provisions. Assistance must be secured from the state health department, particularly with regard to the setting up of uniform standards and procedures among the local agencies involved. The state must also enter into the field of research and the control of difficult and complicated problems affecting large industries, or matters involving more than one jurisdiction.

Finally, cooperation must be secured from industries, water companies, chambers of commerce, and other civic organizations, and of the general public. All of these have a definite part in the program, particularly as it concerns the construction of needed sewage works, disposal systems, and other facilities required for the safe disposal of wastes. Through education, it is expected that such cooperation will be secured, and that gradually one of the most serious problems confronting the metropolitan area of Los Angeles County will be brought under control.

Industrial Wastes

THE INDUSTRIAL WASTE PROBLEM. I.—PACKINGHOUSE, BREWERY AND BY-PRODUCTS COKE WASTES *

By F. W. Mohlman

Chairman, Committee on Industrial Wastes, Federation of Sewage Works Associations; Director of Laboratories, The Sanitary District of Chicago

The final disposal of industrial wastes must be accomplished by processes and equipment used in the sewage disposal field. No matter how much recovery or pretreatment may be accomplished in the factory, there is a residual loss which must be diminished by some type of sewage disposal equipment. Therefore the industrial waste problem ends as a sewage disposal problem and is logically in the field of interest of the Sewage Works Federation.

During the war, industry was given every consideration by public officials with respect to stream pollution, and many examples of pollution were allowed because equipment which might have reduced such pollution was needed more urgently for production of war material or supplies. The alcohol industry, whose product was so necessary for synthetic rubber and smokeless powder, is the outstanding example of a war industry whose stream polluting potentiality was condoned rather than curbed. Also the wastes from manufacture of organic chemicals expanded and led to much stream pollution that would not be overlooked in normal times. Wastes from manufacture of phenol, plastics, butadiene, furfural, phthalic anhydride, penicillin, dehydrated fruits and vegetables and packinghouses increased greatly under the stimulus of war pressure, and even more normal industry stepped up production with no corresponding effort to expand waste treatment facilities.

Now, however, the new techniques of industry must face the responsibility of proper disposal of wastes, and this responsibility is being urged by nation-wide attention to congressional bills, interstate compacts, state water boards and municipal ordinances. Therefore industry has become quite waste conscious and committees, waste disposal research groups, plant research and publicity are being organized on a far greater scale than heretofore. Technical programs of engineering and chemical societies include increasing numbers of papers on industrial wastes, and representatives of industry attend technical meetings and present technical papers in increasing numbers.

With this trend in progress, the FSWA assumes new responsibility to recognize and work with such representatives, as noted in the editorial in the November, 1946, issue of This Journal.

In addition to this recognition, the Industrial Wastes Committee of the Federation has been authorized to enlarge its personnel and to make increasing efforts to obtain papers on industrial wastes for the Journal, to invite industrial members into the Federation and to emphasize wider ap-

* A series of special papers by members of the FSWA Committee on Industrial Wastes.

preciation of its importance in this field. As a start it is planned to include in each issue of the JOURNAL contributed articles by members of the committee on certain phases of industrial wastes activity. The types of wastes to be discussed are as follows: packinghouse, brewery, by-products coke, petroleum, distillery, alcohol, paperboard, pulp, paper, laundry, canning, food processing, synthetic rubber, tannery, beet sugar, dairy, textile, electroplating, copper and metals, pickling and chemicals. These topics will be discussed by members of the committee, which will be enlarged with additional personnel. The new members so far are Wm. S. Wise of Connecticut and Wm. J. O'Connell of San Francisco, in addition to Messrs. Mohlman, Bloodgood, Gehm and Oeming.

In this first contribution, the status of waste production and disposal will be discussed for the packinghouse, brewery and by-products coke industries.

Packinghouse Wastes

Packinghouse wastes originate in the various departments, beginning with stockyards, then from the killing floor, washing the carcass, washing and cleaning entrails, paunch manure, blood drainage, tankage, evaporators, hide drainage, hog hair removal, pickling, cooking, rendering and general cleanup. The stockyards wastes are generally far less concentrated than those from packinghouses and consist largely of manure, urine, straw and stormwater. In the packinghouse, wash water from the killing floor can be highly objectionable, particularly if paunches are slit and contents wasted. Grease is lost in wash waters, evaporator feed or entrainment in vapors, pickling liquors, cook water, and particularly from steam rendering. Dry rendering ought to be adopted by all houses, and would be if there were no premium paid for "prime steam lard." No single house operation can equal the installation of dry rendering for prevention of loss of grease.

Tankage evaporation can lead to excessive loss of nitrogen if of inadequate capacity. Entrainment losses are also troublesome when capacity is limited.

The methods of reducing losses thus comprise: efficient grease-skimming basins, paunch-manure screens, ample evaporating capacity, dry rendering and catch basins. Beyond these salvage measures, wastes must be treated. A well-operated packinghouse should not lose more than 0.2 lb. recoverable grease, 29 lb. 5-day B.O.D., 23 lb. suspended solids, 3.5 lb. nitrogen and 2.6 lb. total grease per ton kill. Volume of wastes should not exceed 4,100 gal. per ton, including all cooling, refrigerating and wash waters.

Treatment of packinghouse wastes follows the processes common to sewage treatment, inasmuch as there is little difference, biologically, between the two types of liquors, except that packinghouse wastes are fresher, higher in grease, with a relatively higher ratio of carbon to nitrogen and the temperature somewhat higher.

The largest packinghouse waste problem is in Chicago, the center of the industry. There wastes with a population equivalent exceeding one million are diluted with seven or eight times their volume of sewage, and the mixture treated by activated sludge at the Southwest treatment works. No pretreatment is given the wastes except a little skimming at the Racine Avenue pumping station. In 1945 the activated sludge process accomplished 91 per cent reduction of B.O.D. and 91 per cent reduction of suspended solids of the diluted packinghouse wastes (as well as of the sewage and other wastes present). Air consumption averaged 0.76 cu. ft. per gal. or 794 cu. ft. per lb. B.O.D. removed.

At Sioux Falls similar high removals of B.O.D. and suspended solids are obtained from a much more concen-

trated mixture of packinghouse waste and city sewage by a multistage process consisting of primary sedimentation, primary backwash high rate filters, intermediate settling, final filters, settling, and finally, activated sludge. The lifting of sludge floc in the final settling tanks by liberated nitrogen gas has been a problem, but it is largely solved by rapid removal of sludge, using specially designed Tow-Bro settling tanks and control of the degree of nitrification.

The use of multistage processes appears necessary in order to obtain a high degree of treatment with packinghouse wastes. Primary washable filters have also been successful at Mason City, West Fargo, South St. Paul and Austin.

Chemical treatment has been applied, using zinc chloride and lime, and now only lime, at the Oscar Mayer plant in Madison; chlorine in large amounts at Hormel's in Austin; ferric sulfate and sulfuric acid at several of Swift's small plants; ferric chloride at Kerber's in Elgin; ferric sulfate and lime at a small plant (Grand Rapids) in Michigan, for awhile by Armour at Cedar Rapids and Tovrea at Pheonix.

Recovery of sludge from packinghouse wastes has not been very successful. The nitrogen content is usually lower than that of domestic sewage and no use has been discovered for the chemically precipitated sludges, although it was thought for awhile that the chlorine precipitated sludge from Halvorson's Process at Austin would make good stock feed. However, toxic compounds ruined this sludge as feed, and there was hardly enough nitrogen for a good commercial fertilizer.

Experience has shown that packinghouse wastes can be treated most successfully by multistage filters or, if wastes are diluted, by activated sludge. Chemical treatment increases the sludge problem, and the B.O.D. or suspended solids reduction are less than those obtained by biological methods. However, for small plants, chemical precipitation may be the only feasible process because of the expense and difficulty of control of biological processes.

It appears that more pretreatment may be used at the packinghouse, and equipment is being developed for this purpose. Studies and installations of Vacuators, Pressurators, vibrating screens, well-designed grease basins, aerated grease skimmers, and special equipment for removal of solids are being investigated. These measures will be of aid in reducing packinghouse wastes to the minimum strength and degree of variation.

Brewery Wastes

Brewery wastes are present in almost any city but have not received much attention as a waste disposal problem. However, wastes from one barrel of beer, in a survey of 28 breweries in Chicago, were found to be equivalent to a population equivalent of 19 persons, based on B.O.D., and to represent 1.7 lb. suspended solids, 0.13 lb. nitrogen and 320 gal. of waste per day. The total U. S. production increased from 53.7 million barrels in 1940 to 87.7 million in 1945, giving a maximum B.O.D. equivalent of 5.43 million persons. Thus this waste is responsible for an appreciable portion of a city's waste load and deserves attention as to salvage and treatment methods.

Salvage of usable products is under active development in the brewing industry. When the Chicago tests were made, in 1937, only one plant had a process for recovering grains and none had any for recovery of yeast. Now grains and yeast are collected from practically every brewery and handled by central companies which dry the materials and sell the product as feed, source of vitamins or proteins, or medicinal products. One company in Chicago handles one-half million pounds (dry) of yeast per year and makes high

protein food or high concentrate vitamins from this former waste. Many other breweries salvage yeast. The food value is surprisingly high, because of the high protein content of the dry yeast. The minimum human daily protein requirement, 70 grams, can be bought for 17 cents, at 50 cents per lb. dried yeast, as compared with costs of an equivalent amount of meat of 44 cents, beef liver 39 cents, milk 33 cents, or eggs 51 cents.

Yeast increases 4 to 1 during fermentation, thus producing an excess of about 0.5 lb. dry yeast per barrel of beer. The total U. S. production thus available for salvage is around 40 million pounds per year, recovery of which would add a valuable food item to the nation's resources.

Treatment of brewery wastes is usually accomplished in the city's sewage treatment works, therefore no special pretreatment is essential, if grains and yeast are recovered. When wastes must be treated by themselves, chemical treatment will reduce B.O.D. only 50 to 75 per cent and sludge is difficult to filter and dispose of. Activated sludge treatment is not too successful, but trickling filters seem well adopted to this waste. A plant with a loading of about 1,500 lb. 5-day B.O.D. per acre-foot has averaged 92 per cent removal of B.O.D. and 85 per cent of suspended solids on presettled wastes at an operating cost of about two cents per barrel.

The brewery waste problem however, is largely that of reducing strength prior to discharge to sewers, inasmuch as breweries are usually located in cities. Therefore the recovery of grains and yeast will go far toward abating this problem, leaving only wash water, press water from grains, and yeast residues as sources of pollution. It should also be emphasized that brewery wastes, even without salvage, are far less concentrated and a much less troublesome problem than other fermentation wastes, such as those from manufacture of yeast, alcohol, whiskey or wine.

By-products Coke Wastes

Wastes from by-products coke plants have long been in the public eye because the tastes have long been in the public mouth. Chlor-phenol tastes have been a problem for the water works chemist, who has largely eliminated such tastes with activated carbon, ammonia-chlorine treatment, breakpoint chlorination, or chlorine dioxide. However, in many cases removal of phenol from the wastes has been necessary, and the first method of doing this has been by use of ammonia-still wastes for coke quenching. This has not been very satisfactory because of corrosion, odors, recondensation of phenol containing water, and incomplete removal, therefore extraction or Koppers plants have been required for removal of phenol. These plants do an excellent job of removal of phenol, a modern extraction plant at Chicago averaging 97.5 per cent removal, but the removal of B.O.D. at this plant was only 77 per cent and others in Indiana showed only 68 per cent. Thus there is a pollution problem remaining even after the phenol is extracted, due to polysulfides, carbon and nitrogen compounds. The effluent should be treated in a sewage treatment plant, as is being done at Chicago, thus giving a final 90 per cent reduction of B.O.D. when wastes are treated in activated sludge plants.

The reduction of phenol, however, is far more important than elimination of final B.O.D., therefore advances in the technique of extraction of phenol are helpful in solving the by-products coke waste problem. Such advances have been reported by Fischer and Gilbert as discoveries in the Ruhr coking practice, namely an aeration process and a more efficient extraction solvent, "phenolsolvan," a mixture of esters of aliphatic alcohols. Whereas 100 to 200 per cent by volume of

benzol is needed, only 10 per cent of the new solvent is sufficient.

No reports are available as to the use of this solvent in working operation either in Germany or the U. S., therefore further data are necessary to determine whether it will supplant present solvents.

By-products coke plants can also lose a substantial proportion of the total phenol in the final cooler, if it is not recirculated and "bottled-up." Therefore this source of phenol should also be investigated, in addition to the ammonia-still liquor.

Treatment of by-products coke wastes in sewage treatment plants is quite successful, if the works are of the complete treatment biological type, and proper loadings are not exceeded. The wastes will require some of the air and tankage in activated sludge operation or a definite number of cubic yards of trickling filters, however, and this cost must be added to the cost of treating sewage. The balance of cost therefore controls the choice of method of removal of phenol.

Results of six two-week tests of by-products coke plants in Chicago gave an average loss of 0.91 lb. phenol per ton of dry coal coked, and 1.90 lb. 5-day B.O.D. Another plant, using solvent extraction, discharged only 0.023 lb. phenol and 0.44 lb. 5-day B.O.D. per ton of dry coal coked.

Discussion

This rather brief discussion of three types of industrial wastes—packing-house, brewery and by-products coke—includes those which have been surveyed in Chicago as to processes, salvage, volumes and losses. The results indicate that certain more or less comparable losses occur per unit processed or produced, and that these losses may be partly reduced by salvage or recovery measures within the plant. Therefore industrial chemists should be familiar with the methods of measurement and unit losses developed by the sewage chemist, who works from samples collected at the sewer outlets. Small losses in fractions of a per cent look very large to the sewage works chemist, who thinks in terms of parts per million. One hundred parts per million is only one one-hundredth of one per cent (0.01%). This looks very low as a process loss, but may loom large in sewage works operation. Therefore, the industrial waste chemist and the sewage chemist need to get together to supplement each other's information. The Federation of Sewage Works Associations is the logical meeting place.

VARIOUS APPLICATIONS OF THE AUTOXIDATION PROCESS *

By Dario Travaini

Superintendent, Sewage Treatment Plant, Phoenix, Ariz.

The autoxidation process is not a new and mysterious, complicated development, for the basic reaction has been known for more than 55 years. It is a method for the cheap local production of ferrous sulfate, ferric sulfate, and dilute sulfuric acid through the simultaneous oxidation of two reducing agents—sulfur dioxide and ferrous sulfate—in the presence of finely divided air. This simultaneous oxidation was commonly termed automatic oxidation, from which the name "autoxidation process" is derived.

Considerable laboratory and pilot plant research has been conducted in Arizona on autoxidation during the past 20 years. The work was conducted mostly by mining organizations interested in the leaching of copper ores. What deterred full scale installations prior to the experiments and pilot plant runs conducted at the Phoenix sewage treatment plant were the facts that the rate of conversion in the cells which had been developed was low, requiring excessive time to complete a run, and that sulfur dioxide gas loss might have caused an air pollution problem with a large installation. These troublesome factors were eliminated at the Phoenix plant in 1938 through the assistance of Mr. Harmon E. Keyes, Consulting Chemical and Metallurgical Engineer, who was then engaged by the city of Phoenix to demonstrate and improve the autoxidation process for application in the municipal sewage treatment plant.

* Presented at 1946 Annual Meeting, Arizona Sewage and Water Works Assn., Tuscon, Ariz., April 16–17.

Autoxidation Process at Phoenix

The question, "Why did the city of Phoenix investigate the autoxidation process?" is often asked. The reason is that in 1937 the city was planning a large annexation program, and the flow at the sewage treatment plant was approaching the designed capacity at an alarming rate. To meet this situation a flow sheet was developed to increase the plant capacity to 16 m.g.d. with the least expenditure. The part time use of a coagulant was anticipated in the proposed layout and the city was after the cheapest coagulant that it could buy or make that would give the desired results. The experiments indicated that ferric sulfate applied at the rate of 0.3 grain as ferric iron per gal. of Phoenix sewage gave average removals of 94.2 per cent of suspended solids and 54.0 per cent of B.O.D. Comparable experiments with 0.3 grain per gal. of alum gave average removals of 89.2 per cent of suspended solids and 50.9 per cent of B.O.D.

A complete description of the autoxidation process was published by Keyes and Travaini in the August, 1945 issue of *Water Works and Sewerage*, so the process conditions will be only briefly discussed here.

As mentioned previously, the autoxidation process accomplishes the simultaneous oxidation of sulfur dioxide and ferrous sulfate by action of finely disseminated air applied under specially controlled conditions. Upon completion of iron oxidation, sulfuric acid may then be produced by continuing the operation. When desired, manganese sulfate may be substituted for

iron sulfate as a catalyst for acid production. For a detailed presentation of acid production by autoxidation, reference is made to an article by Keyes in the May, 1946, issue of *Chemical and Metallurgical Engineering.*

The Phoenix plant consists of a Freeport pressure sulfur burner, a reaction cell of the "air-diffuser" type, and a scrap iron reaction tank, together with necessary pumps, air blower, feeders and storage facilities. This plant is capable of producing ferrous sulfate (copperas) in any strength up to 10 per cent iron as ferrous iron, also ferric sulfate for coagulation in strengths up to 8 per cent iron as ferric iron, or sulfuric acid up to 15 per cent acid with an iron content as low as 0.2 per cent manganese as low as 0.03 per cent. With auxiliary equipment for absorption of waste gas, acid up to 30 per cent may be produced.

Table 1 gives a summary of complete operating data covering a wide range of conditions. In production of ferrous sulfate by contacting the above ferric solutions with scrap iron, the total iron strength is increased 50 per cent. Ferrous sulfate was readily produced up to saturation, or about 100 gm. per liter Fe, when ferric sulfate strength approached about 70 gm. per liter.

The sulfur may be burned under pressure and directly introduced into the solution as sulfur dioxide of any desired strength. When by-product sulfur dioxide gas, as from sulfide ore roasting or calcination is used, a blower is employed to disperse the gas under a solution head of 1 to 4 feet. Extensive cleaning of the gas is not required as the gas is introduced through perforations in lead pipe. Recent improvements in conversion cell design have enabled reduction in SO_2 submergence to 1½ ft. without loss of SO_2. This implies a total pressure at the SO_2 blower, of not to exceed 1 pound. The oxidizing capacity also has been increased simultaneously with a decrease in pressure of oxidizing air. The maximum conversion capacity of the cell has not been attained to date, due to limitations of the sulfur burner.

The air used for oxidation must be filtered to prevent clogging of the fine tubes used to disseminate the air. The small size of the air bubble is an important factor in the success of the reaction, and at Phoenix Aloxite tubes of No. 5 permeability are used.

Any available type of iron scrap may be used as a source of iron. Car bodies and scrap structural iron are preferred, as they are less troublesome to handle than bailing wire. The more rapid action of ferric sulfate, as compared to sulfuric acid, makes feasible the use of coarse iron scrap, in any convenient shape, in the dissolving tanks.

Costs

A plant to produce 3 tons per 24 hours of equivalent anhydrous ferric

TABLE 1.—Summary of Ferric Sulfate Production—Batch Operation at Phoenix

No. Runs Averaged	Type Plant	Gm. per liter		Per Cent Oxidation Fe	Per Cent Conversion SO_2	Oxid. Rate Fe (gm./l./hr.)	Aeration Rate—Per Cu. Ft. Sol. (c.f.m.)
		Oxidized Fe	Acid Produced				
5	Pilot	30.4	2.53	97.1	99.6	9.71	0.614
378	Commercial	26.6	1.8	95.5	99+	3.75*	0.529
1	Pilot	51.6	3.47	97.4	97.5	6.11	0.725
1	Commercial	30.1	0.0	99.0	99+	—	—

* Conversion rate in commercial plant was limited by small capacity of sulfur burner and by starting individual runs with cold solution.

sulfate [$Fe_2(SO_4)_3$] would cost the city of Phoenix under present conditions approximately $10,000, and the daily operating costs for 1946 Phoenix conditions are summarized in Table 2.

TABLE 2.—Daily Operation Costs of the Autoxidation Process at Phoenix

Labor—3 shifts ($261 per month per man)	$26.10
Sulfur—1,470 lb. @ $0.01155	16.98
Scrap iron—1,670 lb. @ $6.50/ton (from city dump)	5.55
Power—421 kw. hr. @ $0.007	2.95
Plant amortization and repairs	6.00
Total per day	$57.58

The cost per ton of ferric sulfate produced in the Phoenix installation is $19.19.

The same plant could produce 6.3 tons per 24 hours of equivalent ferrous sulfate (copperas) $FeSO_4 \cdot 7H_2O$ at a total cost of $60.35 (adding cost of additional iron required) or $9.58 per ton of copperas produced.

The principal competitive substances, now on the market and used in the water works, sewage and trade waste fields are listed in Table 3 with their costs per ton in carload lots, F.O.B. Phoenix as of January, 1946.

The foregoing table indicates that the autoxidation process offers ferric and ferrous sulfate at a low cost. An autoxidation installation is not recommended, however, for a small town where skilled operators are not continually on duty. It is very difficult to fix the minimum size of city on a population basis where autoxidation is applicable, as conditions may vary greatly with different localities.

Applications of Process

With the foregoing background on the autoxidation process the various applications of the process are now briefly discussed.

Water Works

In the water purification field, filter plants throughout the country use large tonnages of coagulating chemicals to remove turbidity, color and a large percentage of the bacteria from the surface water supplies. The coagulants generally used are copperas and lime, ferric chloride, ferric sulfate, chlorinated copperas, alum, sodium aluminate and lime. These compounds are harmless to the consumers because they do not remain in the water, but are precipitated as insoluble compounds and removed by settling and filtration.

It is not the purpose of this discussion to argue the advantages of iron coagulants as compared to alum. It will suffice to say that many water filtration plants are now using copperas, ferric chloride, ferric sulfate and chlorinated copperas for coagulation, and that many more plants may find it advantageous to use the iron salts for coagulation. The autoxidation process

TABLE 3.—Comparative Costs of Chemicals

Material	Approx. Cost per Ton F.O.B. Phoenix, as of Jan., 1946
Alum	$40–$50 (hydrated salt)
Ferric sulfate (solid bulk)	$48.66
Ferric chloride (liquid tank cars)	$80–$90
Ferrous or ferric chloride locally produced	$40–$60 (anhyd. basis)
Standard sulfuric acid (tank cars)	$15–$20 (for 100% acid)
Copperas	$50 (hydrated salt crystal)
Chlorinated copperas	Variable—depends on copperas and Cl_2 cost
Ferric sulfate by autoxidation	$19.19 (as equiv. anhydrous ferric sulfate)
Copperas by autoxidation	$9.58 (as equiv. hydrated salt)

should prove enticing in this field as it offers chemicals at lower cost, locally produced in liquid form ready for use.

Sewage Works

In the field of sewage treatment, a rebirth of interest in chemical precipitation of sewage has become apparent for the past few years. Rapidly growing cities have found their sewage treatment plants inadequate to care for increased loadings. During the war, rapidly expanding industries added thousands of gallons of often strong wastes to the domestic sewage, and with strict priorities and difficulty of obtaining equipment, chemical coagulation was used to handle such overloads without drastic plant enlargements. Many industrial wastes not only increase the B.O.D. load; but they are often of such a nature as to interfere with the sewage treatment process. By the use of chemical coagulation the objectionable characteristics can often be reduced to a point that the ordinary treatment processes are able to function normally. In many cases the coagulant is needed only during periods of excessive loading, or during periods of exceptionally low river stage in the case of inland cities. The use of ferric salts for sewage coagulation is well known among sewage technicians and the low cost local production of ferric sulfate by autoxidation should be welcomed.

Some sewage treatment plants, due to lack of money or land, have found it necessary to condition sludge drawn on sand drying beds in order to increase their capacity. Ferric chloride, ferric sulfate, alum, and sulfuric acid have been used for this purpose. In the field of vacuum filtration of sludge the ferric salts are used almost exclusively for conditioning the sludge. Phoenix is fortunate in that it is not necessary to condition sludge. However, ferric sulfate produced by autoxidation has been tried both on digested and activated sludge to determine its effectiveness as a sludge conditioner.

Tests were compared by running them in duplicate using ferric chloride in one set and ferric sulfate in the other. It was found that the ferric sulfate gave excellent results in conditioning both activated and digested sludge, but the dosage was slightly higher than that required with ferric chloride. When the cost of the locally produced ferric sulfate is compared to the cost of ferric chloride, however, the use of ferric sulfate would be indicated.

Industrial Wastes

In the industrial waste treatment field ferric sulfate has been successfully used in the treatment of meat packing, cannery, distillery, milk and other industrial wastes. The cheap local production of ferric sulfate by autoxidation should be welcomed by the waste treatment field.

As a simplified means of acid production, the autoxidation process has logical application in regeneration of steel plant pickling liquor and in extraction of copper from low grade ores of the Southwest. The pickle liquor adaptation requires separation and calcination of copperas, and conversion of the sulfate content to pickling strength acid. In copper leaching a mixture of ferric sulfate and sulfuric acid can be produced, which is often required in extraction of so-called mixed sulfide and oxide forms of copper. An advantage in each case is in lower plant cost than required for standard acid production, and in saving on freight, in cases where commercial acid cost is high due to freight charges, or where it is necessary to convert by-product sulfur gas to acid. Also, ferric sulfate may be produced from ferrous sulfate discarded from copper leaching operations and may be useful for leaching sulfide forms of copper.

The autoxidation process may utilize

dilute and dirty SO_2 gas of fluctuating concentration, such as cannot be so employed in standard commercial acid plants.

The autoxidation process can also be used in the abatement of air pollution by eliminating SO_2 from waste industrial gas containing at least 0.5 per cent SO_2. These include ore smelting operations, oil refining and boiler stack gases from high sulfur coal.

Conclusion

In conclusion it can be stated that the autoxidation process has been proved successful by 7 years of operation at Phoenix. In general, the cost of iron salts may be reduced about one-half or more by the autoxidation process. This lowered chemical cost should prove beneficial to the water purification, sewage and trade waste treatment fields.

THE AUTOXIDATION PROCESS—A DISCUSSION

By Harmon E. Keyes

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In the excellent presentation by Mr. Travaini of the Phoenix development of the autoxidation process, only a few points may warrant some amplification.

The autoxidation process is often considered somewhat anomalous, as both sulfur dioxide and ferrous sulfate are known chemically as reducing agents. Sulfate formation involves oxidation. Oxidation of either ferrous sulfate or sulfur dioxide by air alone has been proved impractical. However, when both ferrous sulfate and sulfur dioxide are present together in solution and in controlled amounts, they may be oxidized simultaneously and as result of joint association, by finely divided air, to form ferric sulfate according to the reaction:

$$2FeSO_4+SO_2+0_2=Fe_2(SO_4)_3$$

If now, air and SO_2 are further added after iron oxidation is complete, the ferric sulfate thus formed acts catalytically to promote sulfuric acid production according to the reaction:

$$2SO_2+2H_2O+O_2=2H_2SO_4$$

Thus, the process will produce ferric sulfate, sulfuric acid, or mixtures of both, depending on control of the operation.

The explanation given by Mr. Travaini covers development and commercial operation of a successful method of carrying out this process. The chief reasons for the outstanding success of this development, in view of past expenditures on the basic process totalling hundreds of thousands of dollars, and the relatively small sum expended in bringing the improved process operation to its present state are, it is believed, due to three main factors. First, a thorough background of knowledge on fundamentals of the basic chemical reaction involved in SO_2 fixation had been established at the University of Arizona and the U. S. Bureau of Mines. Thus, the time of reaction and the importance of fine air subdivision were already known, as well as results of former plant design and operation applied to ore treatment. Therefore, in developing the Phoenix process and installation, the writer was able to utilize accumulated knowledge in formulating a new approach to meet the more rigid requirements of a sewage treatment plant in obtaining strong ferric sulfate solution without simultaneous acid formation or pollution of the atmosphere by SO_2. This was accomplished by novel design, both of reaction cell and plant flowsheet.

The second outstanding feature explaining the low cost development was the excellent management of the pro-

ject, and the united cooperation of the Phoenix Engineering Department and the personnel of the sewage treatment plant who were involved. The efficient manner in which Mr. Travaini executed arrangements and the never failing interest of the operator, Jack Hatchel, who assisted in the experimental development and maintained the commercial iron sulfate plant operation throughout the war period when material was scarce and no laboratory control was available, contributed substantially to the success of this process.

The third factor of importance was the fact that this process fitted in without conflict with the sewage treatment process, and conversion to cheap iron salt was accomplished in a simple and inexpensive plant which could be handled by a sewage plant operator.

Justification for Process

The basic justification for a process to produce iron sulfates from sulfur and scrap iron is the initial low cost of sulfur as compared to chlorine. For example, sulfur costs 1.1 cents per lb. and chlorine 3 cents per lb., at favorable carload prices at Phoenix in normal times. If 1 lb. of metallic iron scrap is to be made into ferric salt, the required amount of chlorine will cost over 5.6 cents, whereas the necessary sulfur to combine with a pound of iron scrap will cost only 1 cent. This illustrates the potential soundness for use of sulfur, instead of chlorine, in producing the cheapest form of iron salt.

In order to utilize the low cost characteristics of sulfur, a suitable technique had to be developed. The record of 7 years successful commercial operation and the logical conclusions from these results, which have just been presented by Mr. Travaini, speak for themselves as to accomplishment in solving technical and operating problems involved.

In the dissolution of iron scrap to form ferrous sulfate, as practiced in Phoenix, ferric sulfate is much more rapid in action than is sulfuric acid. This is an added reason for employing the autoxidation process, rather than to purchase commercial acid, if large quantities of iron sulfate are needed.

The question of acid production deals with cost relations of commercial acid, or else with utilization of waste or by-product SO_2. Generally, the justification for producing acid by autoxidation is determined by the cost of equivalent commercial acid, possibilities of using waste or by-products as source of SO_2, and reduction in unit labor costs for conversion by autoxidation. It should be pointed out, however, that pH control is a feature of this iron salts process, as free acid may be minimized during iron oxidation or, if desired, any concentration of free acid up to the limits given below may be produced in the solution following completion of iron oxidation. Therefore, iron solutions of any free acid concentration employed in sewage treatment may be produced locally without the trouble and danger of handling concentrated acid.

The above presents a bit of new evidence to establish the practical aspects of an SO_2 conversion process involving selective action in oxidizing iron without forming undesired acid, or in producing relatively strong acid with small amounts of dissolved iron. The sulfur dioxide conversion was so effective that no air pollution problem existed, as shown by Figure 1 illustrating a bird's nest and two eggs located on top of the uncovered SO_2 reaction cell, between the air headers. The fact that this wild bird mistook the SO_2 conversion cell for a part of the natural environment shows how well this process can fit into a sewage works, where preservation of natural wild life and vegetation is of paramount importance. These eggs evidently were laid between intermittent runs and never hatched, as the first run sprayed them with ferric sulfate giving a mottled appearance, so the nest was abandoned.

FIGURE 1.—Bird's nest and eggs located between air headers of the Phoenix autoxidation conversion cell.

Acid Production

Acid production by autoxidation requires a dissolved metal salt catalyst of the type which can exist in more than one state of oxidation. Although a large number of such metal salts are known to function in this reaction, for purposes of this process applied to industry only iron and manganese sulfate will be considered. Manganese sulfate may be added as such to the reaction cell system, or produced from manganese ore by leaching with SO_2 and acid. The concentration of manganese may vary from 0.1 to 1.0 gm. Mn per liter. Up to 15 per cent acid has been produced in this "air-diffuser" type autoxidation cell with negligible SO_2 loss, and up to 30 per cent H_2SO_4 with considerable evolution of SO_2 at the end of the reaction.

Because of its cheapness and availability, dissolved iron sulfate is generally employed as catalyst in acid production by autoxidation. Iron is effective in concentration of not less than 2 gm. per liter Fe, for efficient acid production. Under these conditions acid up to 10 per cent may be produced with negligible evolution of SO_2 from the cells. When the acid reaches 20 per cent some SO_2 is evolved. A maximum of nearly 30 per cent acid has been produced, using dissolved iron catalyst.

With either of the above dissolved catalysts, when acid is desired above 10 to 15 per cent strength, provision is made for return to the cell system of any vented SO_2 that would be objectionable to discharge to atmosphere. Either countercurrent methods of solution-gas contact, or special means of tower adsorption, are employed to prevent SO_2 loss in the higher acid ranges of this process.

One of the distinctive features of the air-diffuser cell is the establishment of a body of solution constantly saturated with finely divided air supplied by calibrated air diffuser tubes, and into which solution body coarsely dispersed sulfur dioxide gas is separately introduced in controlled amounts to give the desired sulfating effect. This separate and simultaneous addition of air and SO_2 gives several advantageous results. The inherent reducing effect of SO_2 is

overcome by adding the SO_2 containing gas, under control, into the oxidizing environment of finely divided air suspended in the solution phase. The SO_2, being much more soluble in water than is oxygen, is readily absorbed into the solution when introduced at a level near the top of the solution body, thus minimizing hydrostatic pressure on the SO_2 distributors so that a single stage centrifugal blower of about 2 lb. pressure may be employed for SO_2 gas introduction.

Although the Phoenix plant operates on the batch principle for convenience in a small installation, engineering plans for larger plants have contemplated continuous flow of solution, preferably through several cells in series. This process may employ SO_2 gas at atmospheric pressure as discharged from a sulfur burner, roaster or calcining furnace, using a single stage acid-proof centrifugal blower to introduce the SO_2 gas into the reaction cell. Cooling of this gas ahead of the blower would normally be accomplished by use of influent or effluent cell solution, according to conditions of operation and the heat relations involved.

Application to Pickling Liquor Problem

A logical application of acid production by autoxidation, which has an important bearing on pollution abatement, is regeneration of acid in waste steel plant pickling liquor. This involves a complete process embracing copperas recovery, calcining to convert sulfate into SO_3 and SO_2, and conversion of the sulfur oxide gases to acid of suitable pickling requirements. High grade iron oxide calcine is a by-product of the process.

This approach to treatment of pickle liquor may be more apparent from a brief explanation of the major process steps. Copperas separation may be accomplished by any desired means, such as partial evaporation and crystallization. Return of acid mother-liquor back to pickling is contemplated wherever acceptable. New developments in copperas separation are expected to cheapen future costs of this step.

In calcining, formation of SO_3 may be encouraged in order to obtain a partial acid recovery by direct condensation and separation of acid mist. The remaining gas, as SO_2, is then converted to acid by autoxidation and added to the fraction of the acid produced by SO_3 separation. A suitable amount of dissolved iron originating from the pickling system is employed as catalyst in the autoxidation cell circuit. The cell conditions oxidize this dissolved iron so that a reduction step employing special adsorption or catalysis with SO_2 is accomplished in a simple packed tower. This liberates a further quantity of sulfuric acid. The final result is acid of 10 to 25 per cent H_2SO_4 and containing from 0.2 to 1.0 per cent Fe which is in the ferrous condition.

A typical acid solution produced in the Phoenix plant to suit pickling requirements analyzed as follows:

Pickling Acid (Grams per Liter)

Total Fe	Ferrous Fe	Ferric Fe	H_2SO_4
8.9	8.8	0.1	195.5

Gas handling from the calciner to the autoxidation cells is conducted as in chemical engineering practice. Generally a continuous flow of solution would be employed, in which the flow to or from the acid cells would be used to collect the SO_3 mist and also cool the gas between the calciner and SO_2 blower.

The above process is a combination of proven operations together with a novel assembly of gas conversion steps designed to simplify and cheapen acid production on a small scale. Because of flexibility of the method and lack of critical features, it is believed the pro-

cess is adaptable to standardization and semi-automatic control.

This process is believed to fit the criteria of a suitable waste treatment method, in that an obnoxious waste is used as raw material and converted back into material needed in the main process. From present calculations, the cost appears comparable in general with current acid costs, particularly when the normal disposal cost of waste pickle liquor and the nuisance element are considered.

Another approach to pickle liquor treatment by autoxidation is in producing strong ferric sulfate solution directly from neutralized pickle liquor. Data on Phoenix operations cover such steps. For example, autoxidation runs have been made in which several per cent free acid was produced, and this solution reduced and neutralized with scrap iron, to give strong ferrous sulfate solution containing up to 7 and 8 per cent Fe. This strong solution was then oxidized successfully in the air-diffuser cell. In the case of waste ferrous sulfate solution, two thirds of the chemical work has already been accomplished on the iron, so that ferric sulfate could be produced at or near a steel plant at very low cost.

Thus, the improved autoxidation process, as conducted using the Phoenix type air-diffuser cell, is presented as a logical solution to the pickle liquor problem. Detailed cost data must await further development.

THE OPERATOR'S CORNER

CRISIS IN CHEMICALS

Some sewage works users of ferric chloride and of chlorine have recently been encountering difficulties in the placement of orders for these chemicals. In at least two cases, the situation has given rise to considerable concern.

It has been reported that some of the large manufacturers of ferric chloride are discontinuing production, and are declining all orders. Companies that are continuing manufacture are hard pressed to meet the demands of their present customers and are not in a position to serve new ones. These producers are handicapped in their efforts to increase production because of the present difficulties involved in new construction.

There are about 80 or 90 sewage treatment plants in the U. S. employing ferric chloride as a sludge conditioning reagent prior to dewatering by vacuum filters. About 150 to 175 plants use the chemical as a coagulant to aid sedimentation. While it is true that substitute chemicals may be used for these purposes, most of the plants will require changes in the facilities available for handling, storing and applying such other chemicals. This obstacle will no doubt be completely circumvented in time through the adaptability and ingenuity which has been characteristic of sewage works operators. In the meantime, the *Corner* will be pleased to receive suggestions from operators who may have already attacked or solved the problem, for the benefit of those who have not.

The situation on chlorine has become confused in some localities, reportedly because of a desire on the part of certain producers to narrow their areas of distribution. If this is the case, a satisfactory readjustment should come about eventually.

The continuing deficiency in the supply of chlorine containers, the main cause of delayed and curtailed shipments during the war, is also a factor in the present chlorine picture. All users will do well to take note of this condition and to act accordingly. Cylinders should be returned to the supplier immediately after they are emptied, so that chlorine production may go forward at the peak rate, unhampered by storage and shipping limitations.

There must be sound business reasons behind the decisions of some ferric chloride producers to suspend manufacture, and of some chlorine suppliers to restrict distribution. Surely, however, old customers of long standing will not be cut off from supplies without proper notice and without a reasonable period in which to make other arrangements. This is especially important in regard to chlorine, because there is no acceptable substitute and on account of the direct public health significance where it is used for disinfection.

W. H. W.

OPERATION OF THE TALLMANS ISLAND SEWAGE TREATMENT PLANT AT NEW YORK CITY *

By Henry M. Rath

Superintendent, Tallmans Island Sewage Treatment Plant, New York, N. Y.

The Tallmans Island plant of the Department of Public Works of the city of New York is of the activated sludge type with separate sludge digestion and provision for the utilization of digester gas for power and heat production. It has been in effective operation for over seven years.

The tributary area is about 17,000 acres with a present contributing population of approximately 130,000. In addition there are the usual service industries, several dyeing establishments, a plating works and a rubber products industry. The present flow is approximately 22 m.g.d. Raw sewage suspended solids averaged 131 p.p.m., and the B.O.D. was approximately 110 p.p.m. in 1946. On several occasions there have been aggravating upsets caused by heavy slugs of trade wastes, but prompt control adjustments have minimized their effects.

The designed plant capacity is 40 m.g.d., which was to serve a population of about 300,000. However, the anticipated building boom that was expected to derive from the World's Fair in Queens in 1939 failed to materialize because of the war. Construction now is underway to extend the system to bring in the sewage from recently completed developments. Additions will be made as home construction is resumed in this fast growing community.

Intercepting Sewers

The 7-ft. diameter interceptor discharges into any one or more of the three grit chamber channels which are located well below grade to permit gravity flow, with the exception of a small volume from a local area which is raised to the interceptor by electrically driven pumps located in a station at the plant. Flow to the grit channels in service is controlled either manually or by float through a 72- by 60-in. sluice gate operated by a hydraulic ram.

Excessive flows, causing a rise in channel level, will raise a float which, in turn, actuates the mechanism to throttle the gate. A klaxon alarm will sound under these conditions. As the sewage level rises in the interceptor a similar throttling occurs at a gate 1¼ miles upstream. As the sewage rises behind this gate and reaches the crest of a permanent weir, the surplus flows over to a by-pass and discharges into a tributary of the East River. Little concern is felt for the polluting effect of this untreated sewage, as overflow takes place only in storms, at which time the wastes are highly diluted by the rain water added to the combined sewer system.

Screening

The first screen in each channel in the grit chamber consists of inclined bars on 4-in. centers. Trash from these racks is raked manually to the separation floor. The material is stored in sanitary cans, which are collected three times weekly and trucked to a local refuse incinerator. The larger amount of screenings, captured on the succeeding 1-in. rack, is drawn up an incline by mechanically operated rakes and dropped into a cutting mill. The macerated material drops through the bottom of the cutter back into the stream. Particles are small enough to pass through subsequent

* Presented at 19th Annual Meeting, New York State Sewage Works Association, New York City, January 17–18, 1947.

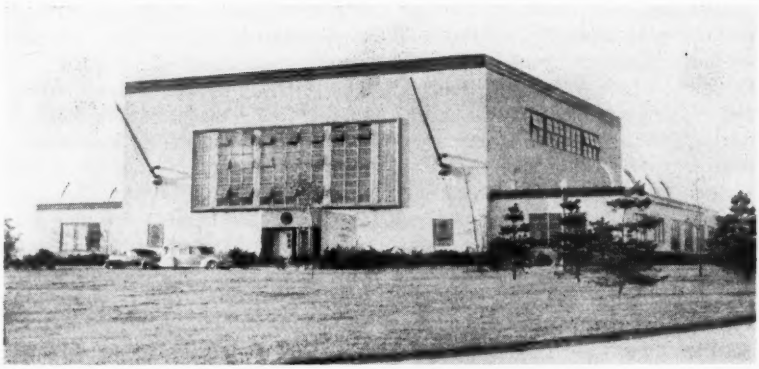

FIGURE 1.—Main building, Tallmans Island sewage treatment plant, New York City.

devices without causing damage. Both the cutter and the bar rack are operated by the same program clock. At predetermined intervals the electrical circuit is closed and both devices go into operation. Normally seven minutes of operation in each half hour are sufficient to keep the rack clear. However, a rise in the channel level will cause a circuit-making float to function and operate the rack and grinder until conditions return to normal. A positioning switch is also used to prevent the rack from stopping at a time when a comb is in the line of flow.

Grit Removal

The grit channels following the racks are 66 ft. long by 12 ft. wide and 8 ft. sidewall height. Velocities are kept fairly constant at 1 f.p.s. by a Sutro weir placed across the channel at the effluent end. The sediment in the channel is collected and removed from the tank by a continuously operated mechanism. This material is chuted from the elevator into the receiving tub of a grit washing device, from which organic material is removed and returned to the channel.

The washed grit is dropped into an ejector of 40 cu. ft. capacity. When the ejector is filled the material closes an electrical circuit to sound an alarm to alert the attendant. Compressed air is used to discharge the ejector contents to an elevated storage tank of 140 cu. yd. capacity. The amount of moisture in the grit is under the control of an operator. A considerable amount is desirable when transporting through the piping system in order to minimize the eroding effect of the more abrasive dry material. This water, with most of the organic material that evades the washing process, is removed from the tank to the head of the plant by a siphoning device.

The removal of the putrescibles from the grit by means of the siphoning device is an incidental but valuable function, as the grit is used for land fill adjacent to the plant. The addition of 2 lb. of hydrated lime to each cubic foot of grit before pneumatic ejection to storage has also been an excellent means of odor control. Daily analysis of representative samples of grit to storage indicate a volatile content averaging 12 per cent. Occasional putrescibility tests indicate little of these substances.

Pumping

After the trash and grit have been removed from the sewage it passes by a free fall from the channel into the wet well, located in the lower regions of the pump and blower building.

This slight fall releases a surprising amount of scum that floats into the well. The capacity of the well is 135,000 gal., which is larger than is desirable for the present flow. Average flowing-through time is 10 minutes.

The stilling effect causes settling of solids and rapid scum accumulation on the surface. An established practice of pumping down the wet well during the early morning hours remedies this condition. Pump speeds are maintained during the day to hold the well to the highest safe level for the purpose of power economy. As the inflow falls off at night, the pump speed is maintained until the elevation is lowered to slightly above the suction bell. Speed is not resumed until the original level is restored several hours later.

This procedure has considerable merit. First, most of the sediment is drawn out at a time when the sewage is dilute; second, the scum is drawn into the pump and delivered to the primary tanks in time for the morning skimming; third, the differential between maximum and minimum flows is lessened, thus maintaining a more uniform flow throughout the 24-hr. day, which condition is particularly desirable where the activated sludge process is employed, and last, only two speed changes are made on the engine driving the pump, which affords a minimum disturbance in the heat balance and in the supply system.

Primary Sedimentation

Three rectangular, straightline tanks are provided for primary sedimentation. These would have afforded a 1-hr. detention for the load originally anticipated. With the present flow, however, two of the tanks in service afford an average period of 1.33 hours.

Sludge collectors operate continuously to plow the sludge to a single sump, from which the material is pumped to the digesters. Such operation of the collectors is also effective in concentrating the sludge due to the rabbling effect of the moving flights. The third, and unused tank, stands by ready for service. It is kept filled with settled sewage to counteract the pressure of ground water. A film of used crankcase oil is floated on the surface to abate insect nuisance and to inhibit corrosion of metals due to oxidation. The mechanism in this tank is operated for a short interval each week for conditioning.

The sludge pumps used are of the dual cylinder plunger type with four speeds. The lowest speed is used normally to avoid cavitation within the sump; to use the positive suction head to best advantage and, of course, to minimize wear. A circuit making clock, adjusted by the operator, is employed to operate the pumps on a time cycle of about 15 min. each hour throughout the day.

Scum is collected by the flights returning along the tank surface. They push the floating substances to the scum gutter curb, which also serves as a tank baffle. Several times a day the attendant lifts the scum over the curb with a broad bladed hoe. Tank effluent is valved into the gutter to give the material a transporting velocity to carry it to a concentration tank. After a short interval of quiescence, the scum is ladled from the surface to cans of about 3 cu. ft. capacity. The ladle is a 9-qt. perforated tar dipper. Water remaining in the scum concentration tank is tapped from the bottom and allowed to run back to the system.

A contractor collects the cans in lots of thirty. The contract for this year calls for payment at the rate of 80 cents per 100 lb. for skimmings as collected. In 1946, 2,700 cu. ft. of skimmings were removed by the contractor. The weight was 169,000 lb., and the grease content approximately 35 per cent. The income was $1,350. This service is of additional value inasmuch as it affords means of scum disposal

other than by digestion; scum in digesters can be a terrific nuisance.

Activated Sludge Treatment

The settled sewage from the primary tanks flows over the long weirs through a flume to one of the two spiral flow, diffused air aeration tanks. Return sludge is added and aeration begins in the narrowed last 100 ft. of the flume. The aerator comprises four passes in series. Each pass is 375 ft. long, 22½ ft. wide, and has a 15-ft. water depth. The total length of the passes is 1,500 ft. If the spiral, representing the flow of the liquor, were stretched out it would approximate a length of 9 miles.

Air at 6.6 p.s.i. is diffused through 12 by 12 by 1-in. carborundum plates ranged along one side of the tank bottom in double file. The plates have a mean permeability rating of 40. The air pattern can be adjusted by angle valves located along the air header that feeds the plate boxes within the tank. Ordinary precautions have been used to prevent plate clogging. Air filters are kept in an efficient condition. Pressures are raised at intervals by applying excess air when surplus fuel would otherwise be wasted. Blower shutdowns are not tolerated, and there has been no appreciable loss of head indicated during the seven years of operation.

The idle aerator is partly filled with clean water to prevent damage to the plates from exposure to dust or frost.

Step aeration, or incremental feeding of settled sewage is provided for by properly located by-passes along the tank, each of which is equipped with venturi meters and control gates. By admitting a portion of the settled sewage through these passes an adjustment can be made in the detention time of the 13,000 tons of sludge in the aeration tank.

This flexibility is useful in combatting the shock of suddenly increased loads, as during a storm when large volumes of rain water flow through and reduce the oxidation period. It is also useful in minimizing the effects of slugs of toxic trade wastes which tend to injure vast numbers of the aerobic organisms, causing a reduction in the biological activity. As soon as these substances become evident, return sludge volumes are increased to provide a maximum number of surviving organisms, and incremental feeding is begun to procure the longer time required for stabilization. A rather interesting experience with trade wastes at the Tallmans Island plant occurred recently when a considerable quantity of chromates reached the plant. (This experience is described in detail in a paper to be published in a subsequent issue of THIS JOURNAL—Ed.).

Ordinarily, standard activated sludge methods are employed with the normal detention at 3 hours. Sludge concentrations in the aerator are varied as conditions warrant between 1,600 p.p.m. and 3,600 p.p.m., with an average for 1946 of 2,300 p.p.m. The amount of air required to keep the sludge in motion averaged 0.33 cu. ft. per gal. last year.

Aerated liquor flows through meters to three of the four rectangular final sedimentation basins. Each tank has a surface area of 11,000 sq. ft. with a water depth of 13 ft. The influent weirs in each tank are 94 ft. long. Instead of expensive sluice gates, stop planks are used for influent control. They have the additional advantage of affording a more gentle and even distribution to the tanks with a minimum of short circuiting.

Detention periods, at present flow, average 3.33 hr., with an overflow rate of 750 gal. per sq. ft. per day. Each tank has a total overflow weir length of 730 ft. The weirs start about one-third of the length from the influent end and extend to about 10 ft. from the effluent end. The effluent from all tanks converges in a common manhole and is discharged to the river through

a 66-in. conduit which terminates 300 ft. offshore.

The tanks are provided with sludge collecting mechanisms similar to those in the primary tanks, except for the absence of the skimming feature. The returned sludge amounts to 39 per cent by volume of the settled sewage flow. This permits the removal of the sludge while it is still fresh and keeps the blanket low in the final tanks. Concentration of this sludge is varied between 4,000 p.p.m. and 10,000 p.p.m. as conditions require. On a dry weight basis, the proportion of return sludge to sewage solids is held at about 25 to 1.

Sludge Thickening

The sludge is removed and raised to the return sludge channel and to the excess sludge concentration tanks by means of air-lifts. Although air-lifts are of low efficiency, they are most desirable from an operator's viewpoint because of their extreme dependability. Controls are most accurate and rates of output are directly proportional to the air applied.

The two excess sludge thickeners are of the center feed, circular type with rabble arms attached to the plow mechanism to aid in the separation of the water from the sludge. Generally it is found convenient to pump rather dilute sludge from the thickeners to the primary tanks where it will settle readily, mixed with the primary sludge.

This cannot be continued in hot weather as septicity occurs in the unstable sludge before it can be removed from the primary tanks. The sludge must then be pumped to the digesters directly. Then the thickeners are brought under more careful control and maximum sludge concentration is accomplished to avoid overtaxing digester facilities. Concentrations of 4 per cent sludge and a sparkling supernatant are possible with influents of 6,000 p.p.m.

The use of chlorine is essential in extremely hot weather to retard decomposition of the sludge with resultant bulking. The average input last year was at 6,600 p.p.m., and the thickened sludge removed contained an average of 3.24 per cent solids. The overflow rate at these tanks is about 400 gal. per sq. ft. per day.

Sludge Digestion and Disposal

There are four digesters with floating covers, each 83 ft. in diameter. The total capacity is 700,000 cu. ft. Two are used as primary digesters, receiving fresh sludge every other day. Each has its companion secondary tank. The secondary tank is decanted every other day and on alternate days digested sludge is removed. The space made available is then filled with top sludge run by gravity through the decanting lines from the primary digester. Each month 1,000 cu. ft. of bottom sludge is drawn from each primary digester, from which samples are taken for analysis for inventory purposes. There has been no difference in the character of top and bottom sludge, nor is too great an amount of scum accumulated on the surface. This clearly indicates excellent circulation without the use of mechanisms.

Temperatures of about 90° F. are maintained in the primary digesters by the circulation of hot water through heating coils suspended in the sludge around the periphery of the tank. The heat originates in the jackets and from the exhaust gases of the gas engines. No heat is applied to the secondary digesters but constant temperatures are maintained by the warm sludge transferred from the primary tanks. Success of this function is an excellent argument for the present trend of preheating sludge before addition to the digesters. Disregarding the additional digestion in the secondary tanks, which produces less than 10 per cent of the total gas, the dimensions of the primary tanks indicate a capacity of 2 cu. ft. per capita per day.

Two storage tanks, to which digested sludge is pumped, are located near the plant dock. Decanting equipment is provided for sludge concentration. The storage capacity is equivalent to the capacity of one of the three self-propelled diesel ships operated by the Department to carry sludge to sea for dumping in a prescribed area. Loading to the vessel is by gravity through a 14-in. diameter cast iron pipe, 400 ft. long. In 1946 sludge vessels made 26 trips to sea with 38,718 wet tons of sludge containing 5.9 per cent solids, of which 44.5 per cent was volatile.

Gas Engines

The gases derived from digestion are used to fuel internal combustion engines, which drive the raw sewage pumps and the air blowers for aeration. Last year 57.32 million cu. ft. of gas was produced—an average of 1.2 cu. ft. per capita per day. This represented 71 per cent of the energy required for power, light, and heat.

The amount of heat available from the gas engine jackets and the exhaust gases is usually adequate for digester and building heating service. However, supplementary heating boilers are available. A standby utility gas supply is also available in the event of a digester gas deficiency. The value of this facility has been reduced by the operation of a recently converted gas engine to a dual fuel engine, which uses diesel oil as a supplement. The engine operates on the diesel cycle. Oil is injected through nozzles and the gas is drawn through governor-controlled valves. The governor functions to compensate for gas deficiencies by controlling the output of the oil injection pumps. Ranges from 7 per cent fuel oil up to 100 per cent are accom-

TABLE I.—Daily Average Operation Data for Year 1946, Tallmans Island Sewage Treatment Plant

Item	1946 Daily Average
Sewage flow (m.g.d.)	20
Grit removal (cu. ft./day)	120
Moisture content (%)	39.5
Volatile content (%)	12.4
Primary sedimentation period (hr.)	1.3
Activated sludge treatment:	
Aeration period (hr.)	2.9
Applied air (cu. ft./gal.)	0.33
Cu. ft. per lb. B.O.D. removed	550
Mixed liquor:	
Solids concentration (p.p.m.)	2,300
Volatile content (%)	69.8
Dissolved oxygen (p.p.m.)	2.9
Sludge Index (Donaldson)	1.2
Sludge Index (Mohlman)	83
Return sludge flow (m.g.d.)	7.8
Return rate (%)	39
Solids concentration (p.p.m.)	6,600
Volatile content (%)	69.8
Final sedimentation period (hr.)	3.3
Overflow rate (gal./sq. ft./day)	750
5-Day B.O.D. (p.p.m.):	
Raw	110
Settled	89
Final	18
Over-all removal (%)	83.6
Suspended solids (p.p.m.):	
Raw	131
Volatile matter (%)	77.5
Settled	94
Final	17
Over-all removal (%)	87.0
Activated sludge concentration:	
Waste sludge volume (cu. ft.)	40,000
Solids (%)	0.66
Volatile (%)	69.8
Thickened sludge volume (cu. ft.)	3,675
Solids (%)	3.6
Volatile (%)	65.6
Decant liquor susp. solids (p.p.m.)	12
Chlorine dosage (summer only—p.p.m.)	25
Sludge Digestion:	
Primary sludge (cu. ft.)	8,000
Solids (%)	5.7
Volatile (%)	63.3
Thickened waste act. sludge (cu. ft.)	3,675
Solids (%)	3.6
Volatile (%)	65.6
Digested sludge (cu. ft.)	3,570
Solids (%)	5.4
Volatile (%)	46.1
Supernatant liquor (cu. ft.)	6,600
Solids (%)	1.0
Volatile (%)	51.1
Gas production (cu. ft. per cap.)	1.2
Per lb. volatile destroyed	12.2
Per lb. volatile added	8.8
Fuel value (B.t.u. per cu. ft.)	670

plished with no appreciable change in engine speed. This engine has been ably reported upon by others.

Operation Data

The plant is under complete laboratory control. Samples are taken periodically at each step in the process and the information derived is communicated to the operating force twice daily for the purpose of making adjustments, if necessary. The samples are composited daily; thoroughly analyzed for the required information, and the findings made available to the Bureau Office within 24 hours.

Table I presents daily average operating data for 1946, and may be interpreted as representing typical conditions and procedure in this plant.

Miscellaneous Comments

Other features that may be of interest are the use of dried digested sludge for conditioning the lawn areas and the many shrub beds and trees about the plant. Two of the trees are of the Asiatic Plain variety, both of which were planted at the same time and under the same conditions. One has been cultivated and sludged twice a year; the other has been merely cultivated. There is a most obvious difference in the growth and condition of the two trees. All of the shrubbery is in excellent condition and its present value is greatly above that of its original cost.

Plant effluent is used for flushing purposes in the grit chamber and in the heat exchangers to carry away surplus engine heat. The effluent is "shown off" by jetting it from the mouths of two ornamental frogs located on a marble island in the center of a large glass-block lined pond surrounded by slate walks, benches, ivy beds, and shrubbery.

The *Chironomid Natan*, commonly referred to as the "midge fly," and which is quite prevalent around the basins of water filtration plants, finds an excellent environment for spawning in and around the final sedimentation basins. They are kept under control by leaving spider webs undisturbed. Hoards of fat spiders spin large webs to trap the insects and prevent them from becoming a nuisance.

About half of the original area alloted for the plant has been developed into a public park. Despite the recreational facilities available in the park, most visitors prefer the plant site. Excellent fishing usually is found at the plant bulkhead and pier.

CHEMICAL TREATMENT OF LOS ANGELES SEWAGE TO RETARD SLIMES AND SULFIDES *

By A. A. Appel

Assistant Superintendent of Sewer Maintenance, Los Angeles, Calif.

As a result of legal action instituted by the California State Department of Public Health against the city of Los Angeles, relative to the pollution of shore waters adjacent to the bathing beaches of Santa Monica Bay, the city was directed by court order to chlorinate or otherwise disinfect the sewage prior to its discharge into the ocean at Hyperion.

Following this directive, the Board of Public Works designated the Bureau of Maintenance and Sanitation as the responsible city agency to consummate the work necessary to comply with state requirements for safe bathing waters. The court order also stip-

* Presented at Annual Meeting of Arizona Sewage and Water Works Assn., Phoenix, Ariz., November 23, 1946.

ulated that the sterilization of the sewage should be started by June 1, 1946, and continued until October 31. In order to meet the date set, immediate and extensive laboratory and field studies for this work were imperative.

During the summer and fall of 1945, the Division of Sewer Maintenance had been conducting extensive odor and mosquito control experiments in sewers, storm drains and open channels, using a chlorinated hydrocarbon called "Cloroben," following its recommendation by the Los Angeles City Health Department.

Preliminary Studies

This chemical, at a concentration of from 1 to 2 per cent, was applied for control of odors, flies and maggots, on sewage screenings temporarily dumped onto the ground for storage. The results obtained in all cases were most satisfactory, not only as to the small cost of chemical involved, but in the simplicity of its application. While the above work was being conducted, attention was directed to the bactericidal and slime-reducing qualities of the chemical, as reported from various cities which had been using it with good results.

As these factors were prime requisites of any chemical to be used by the city in the attempt to reduce the area of beach quarantine, it was decided to experiment with Cloroben by adding 1 to 2 p.p.m. in solution to the sewage being by-passed to a storm drain as a result of a stoppage in a 16-in. sewer caused by the illegal discharge of certain rubber wastes. Tests made of the bacterial count following several hours contact indicated approximately 90 per cent kill, while sewer odors had been eliminated.

Following extensive jar tests by the Los Angeles Bureau of Standards bacteriological laboratory relative to the optimum dosage of chemical required for maximum bacterial reduction in relation to the contact time needed, it was decided that in order to obtain the most efficient results, the chemical should be introduced at the upper terminals of trunk line sewers, so that the sewage would receive treatment while fresh, thus inhibiting bacteria and slime growth and subsequently reducing H_2S generation downstream. From 4 to 9 hours of contact were found to give maximum results. This contact time would, fortunately, be available to approximately 90 per cent of the sewage received at Hyperion because of the length of the sewer lines. These results are comparable to those obtained by Dr. Willem Rudolfs, who had conducted similar tests in New Jersey with this chemical some years previously.

Field Tests

Before proceeding with the mechanics of the application of the chemical to the sewer system, the extent of the various problems involved will be better appreciated if certain pertinent facts relative to the sewer system of the city of Los Angeles are given. The city has an area of approximately 450 square miles. Serving this area is a pipe line system over 3,000 miles in length, varying in type and size from 6-in. vitrified clay or cement pipe to 10½- by 12-ft. tile-lined semi-elliptical conduit. The longest flow, including the main outfall sewer, is over 55 miles, and the sewage which originates near Canoga Park in the upper San Fernando Valley requires 18 hours to reach its point of discharge at Hyperion. There are approximately 25 main intercepting trunk lines which discharge into the outfall at various locations along its route through the city. Appurtenant to this system are 20 sewage pumping plants and four ventilating plants. The estimated value of the entire system is $80,000,000, at prewar construction costs. The average daily flow of sewage at Hyperion is 165 m.g.d.

Having previously installed the dosing barrels at the locations designated, the application of the chemical was started in February, 1946. A shock dose of 5 p.p.m. for the 24-hour flow in each trunk line involved was continued for 3 days. Subsequent dosage has varied from 1 p.p.m. up to 3.5 p.p.m. for a period covering the summer months.

The entire program of application, insofar as equipment was concerned, was inexpensive and simple. During the first weeks of introduction, 30-gal. wood barrels with an ordinary ½-in. gas cock installed near the bottom were inserted in the selected sewer manholes and so placed over the channel to permit the drip of the greatly diluted Cloroben from the petcock to enter directly into the flowing sewage. The petcock was regulated so that the liquid would last over the 24-hour period. Sewer manholes which were near fire hydrants were obviously selected as a matter of convenience in getting water for dilution. As Cloroben has a certain sticky quality, it was found that to obtain a uniform rate of discharge it should be diluted in the ration of not less than 1 to 4.

Gradually, as the program progressed, the 30-gal. barrels were replaced by auxiliary manholes placed adjacent to the sewer manhole. These new chambers each had a capacity of 125 gal. thereby permitting greater dilution of the chemical and a more uniform and reliable flow of the mixture into the flowing sewage. A ¾-in. pipe was placed between the two manholes, with the regulating cock located in the sewer manhole. To service some 50 dosing chambers each 24 hours, routes were mapped and assigned to the various two-man crews who prepared the required dosages for each location. The chemical is non-toxic, but will produce a smarting of the eyes if the concentrated raw material is brought into contact.

Results

As the original intent of the use of the chemical was for the reduction of the bacterial count in the ocean waters adjacent to Hyperion, it was noted during the following months, by daily sampling of the shore waters at 22 stations along the beach, that reasonably satisfactory results were being obtained. However, as the physical condition of the ocean water (suspended solids) could not be changed (which will continue until the proposed treatment plant at Hyperion is completed), the State Department of Public Health has been reluctant to release any portion of the quarantined area.

While the dosing continued, certain beneficial effects were noted to be occurring within those lines receiving the chemical. These facts were substantiated by a periodic inspection of the interior of the pipe and of the appurtenant structures. The amounts of total sulfides in the sewage were also ascertained. The improvements noted to date are as follows:

1. Reduction of Sulfides

For some years past, periodic tests have been made of the sewage at various key manholes throughout the city. These records indicate from 1.5 to 25 p.p.m. of total sulfides present in certain of the trunk lines. The sewage at Hyperion consistently indicated from 5 to 10 p.p.m. Since the introduction of Cloroben, tests made with the La-Motte-Pomeroy Sulfide Indicator show as low as a trace, and not over 1.5 p.p.m. of total sulfides present, even at Hyperion. This same reduction was experienced by the city of Long Beach, where an identical method of application of Cloroben was used. Sewage flows containing from 5 to 9 p.p.m. of total sulfides were reduced to less than 1 p.p.m.

To reduce H_2S in the atmosphere in the outfall sewer, four ventilating stations had been constructed during the previous 10 years at various points

along the route. The stack sewer air discharged at the largest ventilator on the outfall sewer carried as high as 50 p.p.m. of H_2S. Following the treatment of the sewer lines with Cloroben, the operation of all ventilating stations has been stopped, with a resulting saving at the rate of $20,000 per year. Exposure specimens, placed in the inlet chamber of the Centinella siphon, were reported by the Bureau of Standards as being dry and showing little evidence of corrosion following months of exposure there. Sewage odors in and about sewage pumping plants and at Hyperion have been noticeably reduced, much to the relief of the operating personnel. The quantity of Cloroben required at the upper end of a trunk line is easily ascertained by the total sulfide content at its lower terminus.

2. Reduction of Slimes

Past examination of sewer lines showed stringers of slime either hanging from the soffit of the pipe or clinging to the sides at the water level. The surface of the pipe just below the water level was covered with slime growth. Inspections now indicate that a certain amount of sloughing has taken place in the area below the water line. The stringers at the soffit and at the water edge are no longer discernible. Samples of the slime, when introduced into lactose broth, are inactive and will produce little, if any, gas. Cloroben, as stated before, has a "sticky" quality, which adheres to the slime and apparently accounts for the gradual killing off of the slime growth below the water line.

As slime and sludge deposits are strongly suspected as the main source of H_2S generation (Pomeroy and Bowlus; THIS JOURNAL, **18**, 4, 597; July, 1946), the reduction of total sulfides in the sewer lines is readily understood. Inspections were made at the same time in trunk lines from adjoining cities, which discharged into the outfall. These lines had not been treated and the slime conditions were found comparable to our lines prior to the introduction of Cloroben.

3. Reduction of Moisture in Structures

One of the outstanding changes noted was the drying of the interior walls on trunk lines and the outfall sewer. Previously, when inspecting the north outfall, it would be impossible to see for any distance due to the foggy condition of the atmosphere within the sewer. One is now able to see very clearly, with the aid of a large light, several hundred feet or to the next bend. During inspections, gas masks were not required even though a person remained in the sewer for 20 to 30 minutes. All tile liners above the water line were dry to touch and the filler between the tiles was firm, not spongy. When field tests were made to ascertain the quantity of moisture and acid present on the surface of the outfall sewer, the results were practically negative.

The large ventilating station, which formerly exhausted air from six miles of the outfall, was operated for a while following a long shutdown. In the past, the moisture would literally pour down from the exhaust stacks, but during the trial operation no indication of moisture was present. Manholes on the trunk lines, which had formerly been quite wet, were now perfectly dry. The same drying effect was reported by D. R. Kennedy of Long Beach following his use of Cloroben. This drying of the interior of the structures and large lines has been phenomenal. More definite conclusions as to the cause of this drying will only be obtained through further experimentation and observation.

Other Control Measures

To augment the above program, the sewer maintenance division has instituted a planned program of laboratory control of pipe line preservation, and

an industrial waste program of control and inspection to protect the sewers and to eliminate underground water pollution, and thus eliminate those materials which will cause deterioration of the sewer pipe and structures or contribute to excessive hydrogen sulfide generation in the sewage flow. Such a program will also result in obtaining better sewage treatment plant operation.

Acknowledgments

The investigation and experimental work has been under the direction of H. P. Cortelyou, Engineer-Director of the Bureau of Maintenance and Sanitation; field work was under the supervision of R. F. Brown, Superintendent of Sewer Maintenance, while the bacteriological work was conducted under direction of John Young, Director of the city Bureau of Standards.

INTERESTING EXTRACTS FROM OPERATION REPORTS

CONDUCTED BY LEROY W. VAN KLEECK

I have but one lamp by which my feet are guided; and that is the lamp of experience. I know of no way of judging the future but by the past.

—*Patrick Henry*

Twelfth Report of the Minneapolis-St. Paul Sanitary District for the Year 1944 *

BY G. J. SCHROEPFER, *Chief Engineer and Superintendent (Now Professor of Sanitary Engineering, University of Minnesota)*

Knowledge of Use of Garbage Grinders Desirable

The following appeared among other notes from the minutes of the Board of Trustees at its meeting of Sept. 11:

"The chairman stated that he believed, and it was the consensus of the Board, as well as the Chief Engineer, who reported it was also the opinion of the sanitary engineering experts with whom he had consulted, that nothing should be done to prevent or discourage the use of garbage grinders; rather, that it was a matter for the cities to act upon by either requiring that dealers engaged in the sale of garbage grinders be licensed or that they be required to report the sale of garbage grinders to the Building Inspectors' Offices of the two cities, so that permits for their use could be issued for a fee; also, that possibly some additional charge in the way of sewer rental be established for the increased load and demand made upon the Sanitary District's Plant to dispose of the garbage grindings."

(*Abstractor's note:* This suggestion seems timely, as the sale of garbage grinders will certainly increase in the years immediately ahead. All cities and towns should for the present at least have a record of the users of these devices for future reference.)

* For the last previous extract see THIS JOURNAL, **17**, 3, 619 (May, 1945).

Attention, operators! Superintendents of all sewage treatment plants, large or small, are invited to forward copies of their annual reports to LeRoy W. Van Kleeck at the Connecticut State Department of Health, Hartford, Conn., for extracting in this section of the JOURNAL. Carbon copies of typewritten reports will be returned on request.

Screw Conveyors in Grit Chambers Repaired

An interesting method of repair was employed on the 38-ft. screw conveyors which elevate and wash the grit prior to discharge on conveyor belts. After 5½ years of service, the blades on the screw conveyors were worn as much as 1½ in. Instead of purchasing new sections of conveyor, the blades were built up by welding on extensions to return them to their former depths. This method of repair was considerably more convenient and economical than purchasing new conveyors.

Settling Tank Performance

With an average detention period during the year of only 1.2 hours, as compared with a possible detention period of about 3 hours at present flows, the average removal of suspended solids by the tanks was 68 per cent and of the 5-day B.O.D. 39.9 per cent. (*Abstractor's note:* One factor in this remarkable removal with short detention is the relatively strong raw sewage received at the plant. See Table 1.)

Calcium Carbonate in Vacuum Filter Pipes Removed

A method was developed for the easy cleaning of the many small filtrate lines within the vacuum filters. These 1-in. lines would become encrusted with calcium carbonate to the point that their ability to remove the filtrate was reduced. The method employed in cleaning these lines was an interesting one. To remove all of the piping from within—approximately 650 ft. per filter—would have been a lengthy and expensive undertaking. Instead, a dilute solution of hydrochloric acid containing an inhibitor was placed in the filter pan and this acid pumped through the blow line on the filter head.

TABLE I.—Summary of 1944 Operating Data, Minneapolis-Saint Paul Sanitary District

Item	Average
Sewage flow, ave. daily (m.g.)	122.2
Population, design in 1945	910,000
Screenings (cu. ft. per m.g.)	0.95
Total solids (%)	16.0
Volatile solids (%)	85.9
Grit:	
Cu. ft. per m.g.	4.4
Total solids (%)	85.0
Volatile solids (%)	10.0
pH:	
Raw	7.5
Effluent	7.5
Dissolved oxygen:	
Raw (p.p.m.)	<0.5
Settled effluent (p.p.m.)	3.25
Settling tank detention (hrs.)	1.2
B.O.D.:	
Raw (p.p.m.)	175
Settled (p.p.m.)	105
Per cent removal	39.9
Suspended solids:	
Raw (p.p.m.)	285
Settled (p.p.m.)	91
Per cent removal	68.0
Settleable solids:	
Raw (ml. per liter)	6.9
Settled (ml. per liter)	1.3
Per cent removal	79.2
Analysis of sludge:	
pH of raw sludge	6.2
pH of conditioned sludge (filtrate)	8.9
Total solids in raw sludge (%)	7.78
Total solids in thickened sludge (%)	9.01
Total solids in filter cake (%)	32.4
Volatile solids in raw sludge (%)	66.2
Sludge filtrate, suspended solids (p.p.m.)	97
Raw sludge, ave. (g.p.d.)	334,000
Thickened sludge, ave. (g.p.d.)	247,700
Conditioning tanks, detention (min.)	7
Conditioning chemicals:	
Per cent CaO	2.71
Per cent $FeCl_3$	1.16
Filter cake:	
Wet tons per month	292.6
Dry tons per month	94.7
Filter rate:	
Lb. wet per sq. ft. per hr.	10.7
Lb. wet per sq. ft. of filter area used	0.87
Cost of plant operation and maintenance, total	$296,375.76
Per m.g. sewage treated	$7.05
Per ton dry solids removed	$7.20

The filter was revolved during this procedure and the spent acid issued from the openings on the filter drum and returned to the filter pan. With this method a filter could be easily cleaned in several hours time with a relatively small amount of labor. In addition, the revolving of the filter in the acid bath served to remove the carbonate build-up on the drum itself and on the screen.

Vacuum Filter Cloth Washing Method Changed

As early as 1942 a method of washing was developed which did not require removing the filters from service. Instead of at the usual location on the far side of the filter near the take-off plate, the wash-water pipe and nozzles are installed immediately below the top edge of the take-off plate, so that the washing operation is done in the section of the drum between the take-off and the submergence in the sludge, which section is not utilized in the usual installation. A trough suspended immediately above the sludge level returns the spent wash water to the overflow basin on the filter.

Early in 1943, apparatus permitting of this method of washing was installed on an experimental basis on filter No. 4. The experience with this temporary installation led to further development work to overcome the difficulties encountered, which were purely of a mechanical nature and not in operating principle. The washing device was installed on all remaining filters early in 1945.

Experience with the washing device indicates that very material savings in the quantity of chemicals required for conditioning can be effected by washing continuously. The 1945 Annual Report will contain information covering these savings. In addition to the savings in conditioning chemicals required, the installation of the washing device has the advantage of, in effect, adding one more filter to our installation. The saving results from the fact that it is not necessary to remove a filter from service for washing six or more times per day. Furthermore, it is possible to maintain much more uniform tonnage because of removing the necessity of taking filters out of service for washing. As an added advantage the quality of sludge of the filter cake from a moisture content basis is much more uniform, since after every washing, sludge of high water content is produced which resulted in upsetting the operation of the incinerators. An expenditure of $3,000 to revamp all of the vacuum filters has been proven to be well justified.

Degree of Sewage Treatment Increased During Year

Chemical treatment of the sewage as a means of increasing the degree of treatment was not required during the year. However, during the months of January and February, 1944, the navigation pools in this vicinity were lowered in the interest of maintaining satisfactory stream flow in the vicinity of St. Louis. To offset the expected deleterious effects on the lower river caused by pool lowering, the degree of treatment provided in the plant during these months was increased by utilizing all of the settling tanks and providing a detention period of about 2.5 hours, as compared to the ordinary detention period during favorable stream flow conditions of approximately 1.0 hour. By reason of the combination of the higher degree of treatment and favorable river flows maintained by the release of water from the headwater reservoirs, oxygen conditions in the river below the plant were maintained at very satisfactory levels.

Table 1 is a summary of operating data for the year 1944.

Fifth Annual Report of the Gary (Ind.) Sanitary District (1945) *

By W. W. Mathews, *Supt.*

Use of Sludge Gas as Source of Power

Sludge gas was available usually when needed with the result that the value of gas used in 1945 was $22,784.43, which is the highest to date. Conversely, the power bill was the lowest for any one year, amounting to $10,833.24.

From 1941 to 1945 inclusive, 276,046,000 cubic feet of gas were produced, which had a value in terms of power of $109,808.68. This is approximately 31 per cent of the cost of operation of the plant in which it was produced. It is evident from the above totals that real economy in plant operation can be effected through the utilization of sludge gas as a source of power. It has been an important contributing factor in economical operation of the Gary sewage treatment plant.

Brief Description of Plant

The plant is an activated sludge, diffused air type separate sludge digestion. Garbage grinding equipment is included as part of the plant but has not yet been used. Design is based on a flow of 40 m.g.d. or 170,000 population. The plant was constructed in 1939–40 and placed in operation on August 23, 1940. Total cost of plant,

* For last extract see This Journal, **18**, 2, 325 (March, 1946).

TABLE II.—Summary of 1945 Operating Data, Gary Sanitary District.

Item	Average	Item	Average
Estimated population served	100,000	Secondary settling period (hr.)	3.4
Sewage pumped (m.g.)	7,120	Secondary settling (g.p.d./sq. ft.)	647
Average daily pumpage (m.g.)	19.51	Raw sludge:	
Suspended solids removed (lb.)	17,869,388	Per cent total dry solids	4.2
5-Day B.O.D. removed (lb.)	8,730,784	Per cent volatile dry solids	53
Gas production (cu. ft.)	56,198,530	Gas analysis (%):	
Ave. daily gas production (cu. ft.)	153,969	Carbon dioxide	28
Value of gas used ($)	22,784.43	Oxygen	0.02
Reduction in suspended solids (%)	98	Methane	67.5
Reduction in 5-day B.O.D. (%)	94	Hydrogen	3.3
Cost of operation ($):		Nitrogen	1.2
Per m.g.	9.85	Gas heat values (B.t.u.):	
Per capita	0.70	Net	680.7
Per 1,000 lb. B.O.D. removed	8.03	Gross	752.8
Cu. ft. of air used per gal. sewage	0.49	Total gal. digested sludge drawn to beds	7,678,240
Gas production:		Digested sludge:	
Cu. ft. per day per capita	1.54	Per cent total solids	5.3
Produced per lb. solids added	3.09	Per cent fixed solids	51.1
Produced per lb. volatile solids added	5.97	pH	6.9
Screenings removed (cu. ft. per m.g.)	0.16	Total bacteria per ml.:	
Grit removed (cu. ft. per m.g.)	7.6	Raw sewage	943,600
Suspended solids in mixed liquor (p.p.m.)	1,054	Final effluent	214,300
Sludge index	81.6	*B. Coli*-M.P.N. per 100 ml.:	
Suspended solids in return sludge (p.p.m.)	3,907	Raw sewage	4,218,182
Per cent of return sludge	36	Final effluent	153,273
Aeration period (hr.)	4.9	Grand Calumet River data:	
		¼ mile upstream:	
		D. O. (p.p.m.)	5.0
		B.O.D. (p.p.m.)	4.6
		¼ mile downstream:	
		D. O. (p.p.m.)	5.2
		B.O.D. (p.p.m.)	4.0

including garbage grinding equipment and structures, was $1,901,793.57. The plant site, approximately 52 acres, was purchased at a cost of $40,000.00, and provides room for expansion when needed.

Table 2 is a summary of the 1945 operating data.

Annual Report of the Tri-City Sewage Treatment Plant (Pasadena, Calif.) for the Year Ended June 30, 1946 *

By William A. Allen, *Superintendent*

Sludge Disposal

Disposal of excess activated sludge through the facilities of the Los Angeles County Sanitation Districts continues to be a very satisfactory solution to this problem.

Abandonment of Works Indicated

Mr. Charles Gilman Hyde, consulting engineer, states in part in the conclusion of his report on the continuance of this plant:

"All of the estimates of annual costs and all other considerations lead irresistably to the conclusion that the Four Cities (Pasadena, Alhambra, South Pasadena and San Marino, Calif.) should abandon the Tri-City treatment and disposal works and, as County Sanitation District No. 16, join with Sanitation Districts Nos. 1, 2, 3, 5, 8, 15 and 17 in the proposed joint sewerage, sewage treatment and ocean disposal enterprise. It is recognized that the scrapping of any going concern is psychologically difficult. But it must be remembered that the Tri-City plant for the most part has already served through the period of useful life ordinarily assigned to that type of process and to the physical plant which is appurtenant thereto.

Even under the most adverse assumptions as to relative cost of treating the sewage in the two plants under discussion, the calculated savings in annual costs to be effected by the County project over the Tri-City project are impressive."

Table III is a brief summary of the 1945–46 operating data.

TABLE III.—Summary of 1945–46 Operating Data, Tri-City Sewage Treatment Plant

Item	Average
Av. daily sewage flow (m.g.)	11.7
Suspended solids reduction (%)	87.5
B.O.D. reduction (%)	90.5
Operating cost, total ($)	94,537.69
Per m.g. ($)	22.14

* For last extract see This Journal, 18, 3, 554 (May, 1946).

Annual Report of the Sewage Disposal Commission of the City of New Britain, Conn., for Year Ended March 31, 1946 *

By John R. Szymanski, *Supt.*

Description of Plant

The treatment process (Guggenheim) includes bar screens, Triturator, grit settling tank, Parshall flume, dosing tank, aeration and mixing tanks, final settling tanks with sludge return to aeration tanks.

The sludge treatment and disposal units consist of sludge aeration and storage tanks, chemical conditioning, vacuum filtration, incineration or lagooning.

The plant was officially placed in operation on May 1, 1937. It was designed to handle 9 m.g.d. The plant is estimated to be serving at present a population equivalent of 80,000.

Table IV is a summary of the 1945-46 operating data.

* For last extract see This Journal, 18, 4, 741 (July, 1946).

TABLE IV.—Summary of 1945–46 Operating Data, New Britain, Conn.

Item	Average	Item	Average
Population served, equivalent	80,000	Vacuum filters:	
Sewage flow (m.g.d.)	9.95	Days run monthly	19
Daily max. (m.g.d.)	12.5	Hours run monthly	414
Daily min. (m.g.d.)	7.0	Lb. wet filter cake produced, total for yr.	16,953,590
Screenings removed (cu. ft. per mon.)	1,754	Lb. dry solids in cake, total for yr.	6,178,120
Grit removed (cu. yd. for year)	160	Rate (lb. per sq. ft. per hr.)	6.2
Primary settling, detention (hrs.)	1.0	Ash produced from sludge burning, total (cu. ft.)	39,410
Grease skimmings removed (cu. ft. per mon.)	842	Fuel oil used for heating and sludge incineration, total (gal.)	57,652
Chemical dosing:		Suspended solids (p.p.m.):	
Lb. copperas per mon. (when used)	31,000	Raw	238
Lb. chlorine per mon.	6,054	Primary influent	315
Lb. Ferrisul per mon. (when used)	34,367	Primary effluent	179
Air used (cu. ft. per gal. sewage)	0.13	Mixed liquor	1,140
Per cent of returned sludge	10.3	Final effluent	40
Excess sludge wasted to primary tanks:		5-Day B.O.D. (p.p.m.):	
M.g. per month	3.08	Raw	184
Air used for returning sludge by air lifts:		Primary influent	227
Mil. cu. ft. per month	17.9	Primary effluent	157
Primary sludge removed for filtering (gal. per mon.)	612,584	Final effluent	48
Chemicals for conditioning of sludge:		Total iron (p.p.m.):	
$FeCl_3$ (lb. per mon.)	12,044	Raw	31
Wet Prestolime (lb. per mon.)	135,658	Primary influent	35
		Primary effluent	19
		Final effluent	7
		Expenditures (dollars)*	90,632.47
		Per m.g. for operating expenditures	24.95

* Includes $4,375.00 interest on bonds and $10,000 payment on bonds.

Annual Report on the San Diego, Calif., Sewage Treatment Plant for Fiscal Year 1945–46

By Eric V. Quartly, *Supt.*

Sewage Treatment

Throughout the year the sewage treatment plant continued to give primary treatment to the domestic sewage and industrial wastes from the cities of San Diego, La Mesa, National City and the Naval Air Station at North Island.

Comminutors

The two comminutors have been operated continuously throughout the year. Cutter teeth have been sharpened and replaced on an average of every 90 days and it has also been necessary to replace all of the stellite combs on both machines at considerable expense. The efficiency of these two machines has not been as high as anticipated and numerous partially shredded rags pass through the slots, although this condition has been remedied somewhat by changing the manually cleaned bar screen openings from 3¾ in. to 1¾in. (*Abstractor's note:* From the comments concerning grit removal it would appear that much of the comminutor trouble might be laid to inadequate grit removal. Other plants have been troubled by lack of grit removal or placement of machines ahead of instead of following the grit chambers.)

Grit Removal

The detritor has been operated continuously during the year but the over-

load on this unit has been so great that the efficiency of the detritor has been exceptionally poor, with a result that grit and sand throughout the plant has been a major problem, especially in the heat drying system where the abrasion from this material has necessitated abnormal and expensive maintenance.

Grit recovered from the detritor is broadcast daily in designated areas on the plant grounds, and sprayed with DDT for fly control.

Sludge Digestion

Heating of the digesters has been accomplished entirely by the use of live steam injection into the raw sludge prior to entry into the digesters. During the year considerable improvement has been made in the method of applying steam to the sludge. Steam is now applied in a "constant level" concrete box equipped with an overflow weir. Sludge pumped to this box is heated by steam at approximately 3 to 4 p.s.i., applied through four 4-in. vertical perforated pipes; the heated sludge then flows from the box over the weir and to the digesters by gravity.

Chlorination and Odor Control

Application of the chlorine and ferrous chloride to the raw sewage for control of odors and generation of hydrogen sulfide has been continued throughout the year. Ferrous chloride feed rate has been governed in proportion to hydrogen sulfide concentration as determined by laboratory analysis. Iron for the Scott-Darcey process has been obtained by use of shredded tin cans purchased from a local vendor in carload lots.

Fertilizer

During the year, 1,247 tons of fertilizer were produced by the plant for use mostly in citrus groves, sugar beet, bean and potato fertilizing and with a smaller quantity used by nurserymen and home gardeners. Fertilizer has been sold for $17.80 per ton f.o.b. plant storeroom in 100-lb sacks, a contractor furnishing the sacks. A typical analysis of the fertilizer is: organic nitrogen —3 per cent; phosphoric acid, total—2 per cent; phosphoric acid, available —1.25 per cent; potassium—0.27 per cent.

Plant Enlargement

The Currie Engineering Company of San Bernardino has been engaged to prepare detail plans and specifications for enlargement of the existing plant. Work on the plant will proceed as soon as material shortages and other difficulties can be overcome.

Table V is a summary of 1945–46 operating data.

TABLE V.—Summary of 1945–46 Operating Data, San Diego, Calif.

Item	Average
Sewage flow (m.g.d.)	22.6
Total operating cost ($)	149,814.47
Revenue from sale of fertilizer ($)	21,905.77
Net operating cost ($)	127,908.70
Net cost per m.g., excluding depreciation ($)	10.72
Suspended solids:	
Raw (p.p.m.)	334
Effluent (p.p.m.)	111
Per cent removal	66.9
Sludge dewatering and drying:	
Hours of operation per mon.	249
Tons wet cake produced per mon.	497.9
Per cent dry solids in cake	25.1
Cake yield (lb. per sq. ft. per hr.)	1.5
Per cent ferric chloride (dry basis)	6.02
Per cent moisture in fertilizer	10.1
Chlorination and Scott-Darcey Process:	
Lb. chlorine used per mon.	21,337
Dosage of chlorine (p.p.m.)	3.7
Lb. per mon. chlorine as $FeCl_3$ (Scott-Darcey)	6,251
Total lb. chlorine per mon.	27,588
Raw sludge:	
pH	6.6
Per cent dry solids	5.5
Per cent volatile solids	80.4
Digested sludge:	
pH	7.3
Per cent dry solids	4.4
Per cent volatile solids	61.8
Reduction:	
Per cent volatile matter	60.6
Per cent total solids	48.6
Digestion tank temperature (F.°)	96.0

COAL TAR PAINTS FOR SEWAGE WORKS

By M. F. Abrams

Deceased, Formerly Sales Engineer, Wailes Dove-Hermiston Corp., Westfield, N. J.

With the exception of a few industries using strong chemical solutions combined with large quantities of water, no more fertile field for corrosive action exists than in sewage treatment plants. Each year corrosion takes an enormous toll in maintenance work and in damaged equipment.

No two sewage plants are alike in design, and it is doubtful whether any two are identical in the quantity, quality or temperature of the sewage treated. The various treatment plants, however, are made up of a number of more or less standardized and well known units, in different groups or combinations and sizes. Except in the cases of specialized industrial wastes, most of the sewage treated is quite similar in its corrosive influences resulting from the hydrogen sulfide and moisture, together with acids, salts and treatment chemicals such as chlorine, ammonia, ferric chloride and others. Climatic temperature differences will also influence corrosive action to some degree.

There is in addition to painting strictly for preservation the additional item of painting for appearance in offices and other locations where corrosive action may be negligible or non-existent. A very definite line can be drawn between purely decorative painting and that carried out entirely for preservation. There is also a borderline category of structures, equipment and areas subject to deteriorating and corrosive influences where attractive appearance is also desirable. These places will vary widely from plant to plant, as will also the degree of corrosion attack.

Planning the Paint Job

When to paint, what to paint, with what kind of paint, and who is going to do it, must be considered and, of course, the cost ascertained and funds provided. In getting the answers to these questions, weather conditions and plant operation must be considered. If there are varying weather conditions the best time for painting is the spring or fall when the excessive heat of the summer is avoided and at the same time good drying temperatures for all paints prevail. Which unit or space is to be painted at any one time can be determined by availability of that portion of the plant, labor conditions, and operating schedule so as to cause the least inconvenience. The length of time required for the paint job in question must also be considered.

The choice of paint will also depend on the space or unit, upon whether preservation only is desired, or if decoration and cleanliness are the only requisites. In the event of a preservation job only, the factor of availability is an important one. If the space or unit is one that can be removed from operation, and cleaned and painted at relatively frequent intervals without difficulty, a protection of a less expensive but semi-permanent type would be the best. If, however, plant operation is badly disrupted by a shutdown, then the most permanent type of coating available should be used, even though the expense is somewhat higher and the shutdown once accomplished is a little longer. The annual cost of this kind of maintenance, considering shutdown operations, is frequently cheaper in the end. Color in this type of work is unimportant.

Where decoration only is desired, permanence is not of too great importance, as experience has shown that good paint will get dirty almost as

quickly as cheaper paints, although some of the better decorative materials can be successfully washed. In painting offices, laboratories, etc., color is of some importance and a subject of considerable variation in personal preference, but the majority of spaces of this type have been painted with gray, cream or a light sea green or some combination of these. The gloss paints would appear to be better for this type of work than flat colors.

Where a combination of protection and appearance is desired, some careful consideration must be given to the severity of the attack, and then a decision made as to whether the protection required is to be the governing factor, or appearance and color scheme. This will govern the decision as to paint selection in this category.

Protecting Metal Subject to Severe Corrosion

The most severe of the conditions found in the plant will be at submerged metal equipment or at that in closed spaces just above the flow line, such as clarifier arms, scum baffles, sluice gates, and accessories in the clarifiers, also steel shafts for flocculators and steel paddle carriers, etc., in the tanks, including steel air and sludge piping, valve rods, screen frames, effluent troughs and weirs. Also in this group are covered channels, including metal areas between flow line and cover. These units are examples of the type of apparatus that is submerged in sewage all or most of the time as it passes through the plant in successive stages of treatment.

Observation has shown that unless carefully protected, the life of this sort of equipment is materially shortened by severely corrosive conditions in most sewage treatment plants. These are the units too, that must be kept in uninterrupted operation, if possible, as few plants have spare units or capacity to enable proper operation to be maintained while cleaning and painting is done.

When such a job is unavoidable, it is frequently at the price of partial or inadequate treatment. Therefore, when it is done the work should be calculated to last a maximum term of years. Long experience has shown that highly effective protection of areas subject to extremely severe corrosive conditions as described can be obtained with a cold application of coal tar primer followed by a hot application of $\frac{1}{16}$ in. of coal tar enamel.

In 1904 and 1910, the city of Glasgow, Scotland, applied coal tar enamel to the sludge tanks of their sludge barges, and it was reported in 1934 that this material "Continues to give satisfaction. Periodically examined and no surface damage noted." This was one of the earliest recorded applications of this type. Coal tar enamel has been used since 1854 for the protection of certain areas on shipboard on over 30,000 naval and merchant ships. The areas on which it has been used have always been those subjected to severely corrosive elements. The areas consist usually of bilges, tank tops, sumps or drain wells where the salt water, mixed frequently with cargo waste, is quite comparable to sewage in its corrosive action.

Some recent examples of coal tar paint applications in sewage works include the clarifiers, sludge storage and grease removal tanks at New York City's Island plant; clarifiers at the Middlesex plant, Bound Brook, N. J.; collector equipment of the Elizabeth (N.J.) Joint Meeting plant; sludge storage tanks at Freeport, N. Y. and the oscillating screen at the Canal Street screening plant in New York. The three sludge boats serving the Wards Island plant were given coal tar paint applications on the double bottoms, sludge tanks and hull interiors. Sewage conduits have been similarly protected, such as the raw sewage line serving the Maritime and Coast

Guard Training Station at Sheepshead Bay, cast iron sewer mains of the Westchester Sanitary Sewage Commission and the discharge heads and connecting cast iron piping at the Coney Island plant of New York City.

Applying Coal Tar Paints

It is hardly necessary to go into detail regarding the composition of coal tar primers and enamels, other than to say that the primer is a liquid coal tar compound with a volatile solvent which is applied like ordinary paint, looks like a black varnish when applied and dries in from 12 to 24 hours, depending upon weather conditions. The coal tar enamel is a specially refined and processed coal tar pitch, with the admixture of certain fillers and plasticizers to give it the necessary qualities of temperature resistance and ductility.

This enamel is manufactured as a solid, is melted in a roofer's tar kettle and, when applied at proper temperature over the primer, is fused to the primer to effect a strong bond between the enamel and metal. The proper thickness of approximately 1/16 in. provides a coating many times thicker than any possible combination of liquid paints, and the inert properties of the coal tar enamel provide excellent protection against penetration of moisture, gases or chemicals to the metals, and hence corrosion is resisted. Temperature range between sagging and cracking in atmosphere is –10° to 160° F., or in liquid up to about 115° F.

Any material or equipment is only as good in use as its application or installation. Coal tar primers and enamels are no exception to this rule. Inasmuch as the enamel is applied at about 450° and hardens in a matter of seconds, unfortunate results have more than once been obtained where good intentions took the place of skill and experience. A much better job is assured, and in the long run the cost will be less, if this type of work is carried out by thoroughly skilled and experienced workmen.

Too much emphasis cannot be placed on the cleaning of surfaces to be protected with coal tar enamel. With this type of protection the whole success of the work may depend on the cleaning, as this enamel cannot usually be successfully applied over old paint, and never over grease, rust or moisture. Therefore, to prepare the steel for treatment with enamel, every possible particle of foreign matter must be removed.

When possible, the best method is to rough scrape to remove grease, sludge, loose scale, etc., paying particular attention to corners, joints, rivets, etc. in fabricated structural work. Then, if possible, sand blasting will give the best results. The next best method is power chipping and wire brushing and, if this cannot be done, then a thorough hand scraping, chipping and wire brushing. Unusual attention must be paid to cleaning fabricated work, particularly around rivets, angles and joints. In any event, this type of coating should be applied to a bare dry metal surface. When properly carried out, the owner will be well repaid for the trouble and expense involved in the proper preparation of surfaces.

Cold Coatings

There are some parts of the plant at which repainting and maintenance can more easily be carried out than on those areas on which the hot enamel is most desirable, but where at the same time a corrosive condition of more than ordinary proportions exists due to gases, moisture, etc. Examples of such equipment would be the framework of bar screen and vacuum filter equipment, floating covers on digesters, cans, wheelbarrows or cars for handling sludge and screenings, and a great many other pieces of equipment or structures which are subject to severely corrosive conditions but which can be spared for occasional cleaning and

painting without disturbing plant operations. There will naturally be borderline cases where it is difficult to choose between the more permanent but more expensive hot enamel and the semi-permanent, but more easily and cheaply applied cold coating.

On these areas where the cold coating of a semi-permanent nature is chosen, tests and actual application over the past ten years show that a heavy coal tar base paint having a thixotropic property or "false body" gives superior results. This type of paint has the same inert base as the coal tar enamel and the same high resistance to moisture, fumes and gases. When properly applied in two coats it has a thickness of between 1/32 and 1/64 in. (two coats at 100 sq. ft. per gallon per coat is a good measurement), and will give good protection where hydrogen sulfide and similar elements are present.

Cleaning for cold applications should be thorough to remove loose rust, paint, oil, grease, sludge, etc. Where old paint is thoroughly aged, however, this cold paint can be successfully applied over it. This type of coating appears to be a thin jelly in the container but when thoroughly stirred quickly changes to a liquid. It brushes easily but no attempts should be made to spread it thinly as would be the case in an ordinary paint job. The proper method is to flow it on as thick as can be done conveniently with a brush. It is a dull or semi-gloss black when dry.

Application to Concrete

On concrete surfaces subject to the deteriorating action of gases and acids in sewage treatment plants, particularly above water level both in concrete pipe and plant structures, coal tar coatings have provided the protective answer in many instances. Cleaning requirements are the same as for metal, with the addition that the concrete should be dried out thoroughly. Any disintegrated concrete should be chipped out and any cracks cleaned out.

A primer of the proper coal tar solution, thinned with a suitable coal tar thinner in proportion of three parts of solution to one of thinner, should be brushed or sprayed on. This will dry in a few hours. Two coats of the heavy coal tar paint to a total thickness of between 1/16 and 1/32 in. should then be applied, as in the case of the steel surfaces.

Maintenance may be continued by applying an additional coat, after cleaning, at reasonable intervals when other maintenance work is being carried out. If this is done there should be no reason for concern due to damage to concrete surfaces. In addition to the protection, concrete surfaces so painted are much more easily cleaned of sludge, scum and grease. Appearance is generally improved, particularly on the walls of tanks and channels.

Areas Subject to Minor Corrosion

There are some areas where there is some corrosive influence which could not be considered sufficiently severe to require unusual or extreme care, but at the same time requiring more consideration than ordinary office or residential property. Included in this group would be valve stands, railings, machinery guards, walkways and sash in buildings where there is some escaping gas, and similar exposures. Here a coating is desirable giving good protection from the attack of gases and moisture, and at the same time having an appearance value.

In this instance two or three coats of a first quality black coal tar solution is suggested. It provides strong resistance to fumes and moisture and at the same time has a brilliant black gloss finish. This coating is applied by brush or spray in the same manner as ordinary paint or varnish, and provides high resistance to existing gases and vapors.

As to offices, garages, laboratories, etc., where appearance is the main factor, it is safe to say that a good paint or varnish supplier can furnish a choice of colors and materials. Perhaps the synthetic base vehicle paints will give the best service for this work. It should be repeated that careful cleaning and preparation and the use of good quality material in this field also will be worth while. Trisodium phosphate in water does a first-class job as a washing solution before painting. A cheap paint job is nearly always the most expensive one in the end.

Moist Surfaces

There is one painting problem in sewage works for which up until quite recently there has not been any very satisfactory solution. That is those spaces, areas or items of equipment which, due to condensate or other operation conditions, could be cleaned of muck, dirt, etc., but could never be thoroughly dried. This is true both of many concrete and steel units. In the past, painting has at best been difficult, many times impossible. If the paint stayed on such areas at all, its life was short and protection from corrosive action was temporary. Peeling usually followed quickly after application, and the whole process was unsatisfactory.

The coatings mentioned previously have all required a thoroughly dry surface for successful use.

There has been produced during the last two years a coal tar base material, which can be described as an irreversible coal tar emulsion, that can be applied to wet surfaces so long as the wetness does not exist to the point where the water is running down. As a matter of fact, better results are obtained with a slightly damp surface than with a dry one. In appearance and thickness the coating is quite similar to the heavy coal tar paint described previously. As a matter of fact there will be many instances where a choice between these two materials would be difficult, particularly on concrete.

The vehicle of the emulsion type material is water, and it can be thinned slightly with water if desired. Application could be either by brushing or spraying, at about 1/64 in. per coat. Color is a grayish black, dull finish.

This new product has been applied under various conditions, indoors and outdoors, subject to many types of fumes and dilute acids and alkalis. From extensive tests, both laboratory and field, it has shown corrosion resistance and waterproofing qualities very favorable in comparison with the heavy coal tar paints mentioned early in this paper.

One limitation which might be important to sewage plant engineers and operators is that this coating must be shipped, stored and applied when freezing temperatures are not expected, as once the water vehicle is frozen the coating is spoiled. Once applied and dried, no damage would be done by freezing. Drying time is quite rapid. On a day when there is low humidity and temperatures of 60° or better, a period of 4 hours would probably be sufficient, assuming, of course, good air circulation in the zone of application.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora (Illinois) Sanitary District

February 4—No apology is ever necessary where safety is the subject. We cleaned up a serious potential danger spot today in the form of a long heavy pipe key suspended from a 6-in. gate valve on an overhead sludge transfer

line and attached to the valve stem only by a ¼-in. set screw. This was a veritable "Damocles' sword" for someone sooner or later.

A strong bracket, bolted to a convenient roof truss and a pipe sleeve, changed this arrangement to a permanently safe one.

February 27—Still thinking of safety, we called on the president of the District's Board of Trustees on our way to the plant this morning. Among other things we showed him a paragraph from a recent issue of *Engineering News-Record,* in which was reported the recent sewer explosion at Terre Haute, Ind., caused by the accidental loss to the sewer of 2,000 gal. of benzol by a local chemical concern. The blast resulted in the complete destruction of eighteen blocks of 8-ft. sewer, the total loss being estimated by the city engineer at $150,000. We also mentioned that some years ago Grand Rapids, Mich. lost four blocks of 4-ft. sewer by an explosion resulting from the accidental loss of cleaning fluid from a laundry on the system. It cost the laundry $10,000 which was finally paid just one hour before court convened to try the case. President Bernbrock was not only interested, but ordered your Logger to rewrite the story for the local papers, with appropriate admonitions to our industries. Users of flammable and explosive materials must be reminded occasionally of the hazards they may cause—otherwise they may become careless.

March 5—One of the provoking things about general plant operation is one's frequent failure to see the obvious and do the things that make operation simpler and/or safer.

Take, for instance, our Rathbone sewer problem. One hundred feet back from the mouth of this 8-ft. sewer the District's main interceptor crosses it at right angles and in such a way as to form a dam about 3 ft. high, since a part of the interceptor lies above the floor of the Rathbone sewer. The dry weather flow collected by this sewer is passed to the interceptor through a 12-in. elbow, flush with the floor of the sewer and on the upstream side of the interceptor. Storm flows jump the dam to the river but also jam the orifice with trash, sticks and rags which must be removed many times during the year. For years the only approach to this trouble spot was by scrambling down a steep bank, grabbing at a short wing-wall and attempting to get around it without falling into the river (Figure 1). It was even harder to scramble out. Once inside, it was a hazardous journey up to the

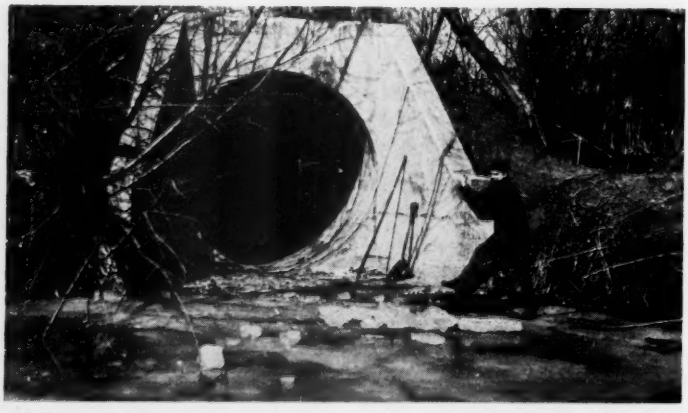

FIGURE 1.—Entrance to the Rathbone sewer interceptor opening in days gone by.

FIGURE 2.—New manhole giving access to the Rathbone sewer interceptor. Note smile.

interceptor, slipping along in the dark on the slimy floor of the sewer. To traverse that 100 ft. at times seemed a mile. At the end of this unpleasant trip it was necessary to poke around blindly with a rake until the interceptor opening was cleared.

All this is no more. Cooperating with the city engineer, a manhole has been cut into the roof of the Rathbone sewer just above the dam (Figure 2) and an iron ladder fixed in place. Now there is safety, light and a quick dispatch of business. What irks us is why we did not do this long ago!

March 12—This is indeed a red-letter day. It contained an unusual and pleasant surprise of the "man bites dog" variety. A representative of the local power utility called to announce a new rate schedule applicable to governmental bodies only, giving us a rate reduction of more than 10 per cent for the current required to operate our two downtown pumping stations. The new rate is immediately effective.

In these days of rising prices this made an interesting paragraph to add to our monthly "confessional" to the Board of Trustees.

March 17—One's desk is not the only thing that should be straightened up now and then. Today we completed a 2-week session of cleaning up the laboratory. It was a mess for the time being, but the results amply justified the inconvenience. Everything in it was either cleaned, painted, varnished or polished. Unused apparatus was sorted back to its normal drawer or cupboard. Junk was junked and complete order restored.

The color scheme was completely changed with a new paint job, from drab browns and dark tans to a light quiet green for the walls and ceilings, and dark ivory for the desks and cupboards. The table tops were recoated with black "Tropelite" varnish. The finished results acted like a tonic.

Actually this was a must job in anticipation of the fact that the Aurora plant is to be host for two days this summer to the annual meeting of the Illinois Association of Sanitary Districts. (Here is an honest man! Some superintendents who display a spotless and glistening plant to convention visitors hesitate to admit that just a few special preparations might have been made for the occasion!—*Ed.*)

March 20—Some breakdowns are peculiar and their causes not easy to find. One of the day operators reported today that he had shut down the No. 2 clarifier mechanism because the motor was smoking badly and had locked. For some reason the thermal relay had

failed to operate. The motor was taken apart and fortunately was not found seriously damaged. It had obviously been running on two phases.

It was a day or so, however, before we finally located the initial cause. The Dorr Traction Clarifier has three long brass slip-rods through which current passes from the center column to the motor. The standards supporting these rods are bolted to the frame and insulated from it by hard fiber rings. One of these insulators was found badly crushed, causing a short in one phase.

March 31—Engaged in a bit of cooperative sewer planning today.

A local real estate man plans to build nine houses on Sherman Ave. and six houses on a street crossing Sherman and running east and south from the intersection. The 30-in. interceptor in Sherman lays from 12 to 18 ft. deep in loose gravelly soil, and is the only sewer available. No house connections with risers were provided on this sewer, and lateral trenching for so many houses would be both expensive and dangerous.

The trustees approved our suggestion that this man be permitted to lay an 8 in. sewer in a trench 8 ft. deep in the parkways of the two streets, with a single connection to the interceptor at the corner but with the following provisos: (a) the entire system comprising about 900 ft. of sewer to be trenched in one operation, (b) four manholes to be built in the system to locate and identify the sewer line and for rodding purposes, and (c) the house connections to be placed and their locations accurately spotted on the District's maps, since all the houses were not to be built at one time.

Thus our client was given a safe and economical plan and his clients were reasonably protected by a properly designed sewer that could be easily located and maintained.

April 2—Lewis Birdsall and his assistant, Mr. Barrett, of the Chicago office of the General Chemical Co., called this morning during our "cocktail hour" (while we were titrating B.O.D.'s). His greeting was interrupted by an exclaimation as his eye lighted on the stoppers in the milk jugs we use for storing composited samples of sewage for weekly determinations of total nitrogen and oxygen consumed. These stoppers were improvised by using 2-in. sponge rubber balls. They answer the purpose very well.

Then he noticed our pet fountain pen filling arrangement—a large sized fermentation tube clamped to the standard of a small ring stand and filled with ink, leaving both hands free to manipulate the pen. Upon this display of interest we had to show him our latest laboratory improvement. We had replaced the usual rubberized cloth cover at our fine balance with a plate glass housing. The housing is large enough to permit us to work comfortably at the balance and is enclosed by a sliding door for the lower half of the front. The utility plate glass pieces required were each rimmed with copper strips formed into a "U" shape. The several pieces were then soldered together using copper angles. It is attractive and permanent and cost less than $20.

April 17—Just across the tracks from us is being built the largest wallpaper printing plant in the United States. They plan to work a 20-hour day and ultimately to have forty printing machines. Some of the buildings are over 1,000 feet long.

Since the color body used is a fine clay to which is added casein and/or protein, together with the color pigments, this plant will produce a serious industrial waste problem. Laboratory studies of typical wastes from their Chicago plant indicates that the waste will carry 8,000 p.p.m. of suspended matter, or about 34 tons per million gallons. Flow charts submitted indicate a daily flow of such waste of up-

wards of 40,000 gallons. Due to the small daily volume discharged no B.O.D studies were made but this value is known to be high. It is equally impossible to discharge this load either to our treatment plant or to the Fox River. When we mentioned this problem to Chemist L. S. Kraus of the Peoria Sanitary District the other day, however, he said that he would give anything if he had such a waste to help settle light sludges in his digesters.

After several conferences with the company officials they were advised that they must provide pretreatment to reduce the suspended matter to 100 p.p.m. or less, which gave them a little tolerance against those days when their treatment plant might be in trouble. Fortunately, coagulation studies made on the waste show that it coagulates nicely with plain alum without pH adjustment, and that a properly designed chemical precipitation plant will do a good job.

One of the company's problems is the disposal of the sludge. It has been suggested that their research department study the possibility or reuse or conversion into something useful. They were further advised to seek the assistance of properly trained consultants to plan their treatment plant.

April 25—Carl Duy, Superintendent of the Aurora Water Department called today to say that he had a letter for us. It proved to be a piece of direct mail advertising from the American Hot Dip Galvanizers Association, Inc. to which was attached a reproduction of the lower part of page 729 of the July, 1946 issue of SEWAGE WORKS JOURNAL. Attention was directed to our story on hot dip galvanizing as practiced in our own shop.

Which pleases us immensely, because we know that at least one subscriber to the JOURNAL reads our column!

April 30—A timely suggestion. Do not forget to write to the American Public Health Association, 1790 Broadway, New York 19, N. Y., for your copy of the water and sewage man's "Bible"—the brand new (9th) edition of "Standard Methods." It is the best edition yet and costs $4 plus postage.

POSSIBLE USES OF DDT AGAINST INSECT PESTS ENCOUNTERED IN SEWAGE TREATMENT *

BY ELTON J. HANSENS

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The insecticide DDT (dichloro-diphenyl-trichloroethane) is a wartime development which has been much publicized. Results obtained with this material by the armed forces in control of human lice, malaria-carrying mosquitoes and various other insects affecting man have been spectacular. A large number of well written and authoritative articles have appeared in popular magazines and scientific journals. Some of the stories one hears about the chemical are obviously much exaggerated.

An extensive report on the early development of DDT is contained in the February, 1944, issue of the *Journal of Economic Entomology* (Annand *et al,* 1944). An account of the life history of the discovery of DDT is included together with more than fifty short notes on results of using the material against a wide variety of insects.

DDT is different from standard insecticides in one important respect—its residual action. If a deposit of

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology. Presented at 31st Annual Meeting, New Jersey Sewage Works Assn., Trenton, March 20–22, 1946.

DDT is properly applied it will continue killing insects which come in contact with it for as much as a year and in some cases even longer. The material is insoluble in water and this characteristic is responsible for the residual toxicity to a large degree.

A great deal of research remains to be done even though a large number of facts have already been amassed about the material. It might be well to mention a few of the things yet to be found out. We need to know what the material will do to a large number of insect pests on which it has not yet been tried. We need to know more about how the material will affect other animals and plants. We need to know whether dangerous quantities will accumulate in the soil and bodies of water over long periods. We need more information particularly about the effects of the material on humans and possible dangers attendant upon its use. There are many other gaps in our information which might be cited.

Our knowledge of the mechanism of action of DDT on insects is incomplete. Apparently the material is both a contact and a stomach poison. As a contact insecticide it affects the nervous system. Shortly after the insect rests on a treated surface it becomes restless, movements become jerky, tremors develop and finally there is paralysis which ends in death. This process is a slow one and death may come hours after the insect has received a lethal dose of the poison. Consequently, the effects of the chemical often can be measured only by the absence of the insect rather than by the presence of dead ones.

Application of DDT

Since DDT is insoluble in water it can be used simply as a water suspension. Various special formulations known as wettable powders have been developed. Against insects affecting man, however, DDT is usually used as a dust, as an emulsion, or is dissolved in some solvent such as oil. Dusts are made by diluting and mixing DDT with a dry powder such as talc or pyrophyllite. Usually a 5 or 10 per cent dust is used.

Emulsions are prepared by dissolving the DDT in some organic solvent and adding an emulsifying agent. The stock emulsion of DDT, solvent and emulsifier is then diluted with water to the desired DDT concentration. When the stable emulsion breaks after application, a deposit of fine DDT crystals is left on the sprayed surface.

The simplest method of applying DDT in liquid is to dissolve the material in fuel oil or some other suitable petroleum oil and to spray or paint the liquid on surfaces to be treated.

The application of DDT to obtain its residual effect is different from the usual method of applying a contact insecticide where the object is to contact the insect and where kills are obtained only by contacting the insect with the toxic material. On the contrary, DDT can be applied when no insects are present, the object being to lay down a uniform deposit of fine crystals. Then when an insect rests on the treated surface it picks up a lethal dose and subsequently dies. It is this use of a residual spray deposit which is of most use against such insects as flies, mosquitoes and roaches.

The dosage of DDT varies depending on the insect and other conditions. Each insect presents a special case of its own and dosage may vary with conditions. For instance, a heavier dosage appears necessary out of doors where there is exposure to the sun than would be required indoors.

Limitations of DDT

Some insects are little affected by DDT, but aside from this, there are other limitations to the use of the material. In winning the war protection of men from insects and diseases was of greater importance than the damage which might result to other forms of

life. In civilian areas, however, such considerations are of importance.

We therefore must determine not only that a certain quantity of DDT will kill mosquito larvae but also that that dosage will not kill fish or other beneficial life. A great deal of work has been done along these lines.

We now know that more than half a pound of DDT per acre applied in oil is dangerous to fish. Considerable work along this line has been done in New Jersey. In 1945 Ginsburg showed that DDT was highly toxic to goldfish in the laboratory and that it also killed black bass, catfish, and minnows in the field. It was shown that as an emulsion DDT killed goldfish at a dilution of one to 2,500,000. It was also demonstrated that DDT is most toxic to fish when applied in colloidal dispersion, less toxic as an oil emulsion and least toxic as a dust.

Other tests showed that DDT applied in oil against pest mosquitoes in quantities sufficient to obtain residual toxicity would also kill practically all other aquatic insects. In some cases snakes and frogs have also been killed. Eide *et al* (1945) have obtained somewhat similar toxicity data.

There are still many conflicting reports as to whether any harm may result from application of DDT to warm-blooded animals as a spray, in emulsions, or in solution. Also it is not known what effect DDT may have when eaten in or on food. Some facts are clear-cut. As a dust, the material appears completely safe on man and animals, provided large quantities are not ingested. There is also definite evidence that DDT in oil can be absorbed through the skin and that more is absorbed from vegetable oils than from petroleum oils. DDT is not a poison in the same sense as are arsenic, lead and fluorine, but it should be handled with due respect.

Precautions in Handling DDT

All available information indicates that DDT is not dangerous to man if it is properly handled. Many of the solvents used in DDT mixtures also may have harmful effects if not handled properly. In mixing DDT in xylene or oils, rubber gloves should be worn. When clothing becomes wet with DDT solutions or emulsions, it must not be worn. The hands should be kept free of the concentrate and should be washed frequently with soap.

During spraying operations, particularly in enclosed places, a respirator and goggles should be worn. DDT sprays should be kept away from food and food utensils. Dizziness and skin irritation following handling of DDT have been reported due to solvents used in the mixtures. To date no case of known DDT poisoning has been observed in humans.

Possible Uses on Insects Encountered in Sewage Treatment

The three insects most often giving trouble in sewage treatment plants are the *Psychoda* flies, houseflies, and mosquitoes. All three of these insects might be controlled successfully by the use of DDT, but further experimentation is necessary. In a review of the literature, few references were found to tests of DDT on these insects in sewage disposal plants.

Psychoda

Psychoda flies have habits such that treatment with DDT would appear to be relatively simple. However, no reports have been found of tests made against *Psychoda* nor is there any reference to the effect of DDT on bacteria of the sewage filter beds. It would seem that tests along this line should be made and that they would be relatively simple field tests. Probably a spray or dust with a low concentration of DDT would be effective. (*Note:* Considerable work has now been reported on the methods and effectiveness of filter fly control with DDT. Several excellent references will be found in the 1946 volume of THIS JOURNAL—*Ed.*)

Houseflies

As for the housefly, considerable tests indicate very satisfactory control of both adults and maggots in a variety of situations. Some commercial fly sprays now contain a small quantity of DDT in addition to other toxic chemicals. These sprays are the so-called "space sprays" which kill the insect by actual contact. The spray must hit the insect in order to kill it, and there is scarcely any residual effect from such a spray.

DDT has its greatest use as a residual deposit which will continue to kill over long periods. With a residual spray properly applied, kills have been obtained as long as a year after application under favorable conditions. Experience in New Jersey indicates that control can be maintained for 6 to 10 weeks by a single application of DDT.

To obtain a residual deposit, DDT can be applied either dissolved in a volatile oil, such as kerosene, or as an emulsion. A deposit of 200 mg. per square foot is generally regarded as the most effective. To obtain this deposit it is recommended that a spray containing 2½ per cent DDT be used on unpainted surfaces and that a 5 per cent spray be used on well painted surfaces which are non-absorbent, half as much liquid being necessary in the latter case to wet the surface thoroughly.

The best type of nozzle is the recently developed one which gives a fan-shaped spray. A knapsack, compressed air sprayer, or a power sprayer is satisfactory for application of the spray. The U. S. Public Health Service has developed standard materials and procedures which it uses in its DDT residual spray control program for malaria mosquito control. These methods are applicable to fly control, if care is taken to apply 200 mg. of DDT per square foot.

It would seem that residual sprays of DDT around sewage treatment plants, particularly in buildings, would be a material aid in reducing the fly problem. In such use, either an emulsion or a solution in regular or deodorized kerosene should give satisfactory results.

DDT has been used with varying success on breeding areas of flies. When manure was thoroughly sprayed with a water emulsion of 0.1 per cent DDT, flies were controlled. In some cases, surface application of DDT to a manure pile has also been successful. It is difficult, however, to get the cooperator to spray the surface each time fresh manure is added and in these cases fly control is incomplete.

Olson and Dahms (1945) in laboratory tests treated a mixture of completely digested sludge and green sludge with 10 per cent DDT dust and 0.25 per cent DDT emulsion along with other materials. They found that the emulsion was not very effective against maggots. The dust gave good control in that it either killed maggots or prevented emergence of flies from the puparia. Surface application of 15 lb. of dust per 100 sq. ft. gave control of emergence. Ultimate control resulted with the use of 1 lb. of 10 per cent DDT dust per 100 sq. ft., i.e., adults died after emergence.

Mosquitoes

A residual spray using 5 per cent DDT in oil or an emulsion with a similar amount of DDT is now being widely used for control of adults of the malaria-carrying mosquito, *Anopheles quadrimaculatus*. Experiments in New Jersey show that such an application has continued to kill resting mosquitoes for more than a year. While *Anopheles* mosquitoes are rarely encountered in polluted waters a residual deposit of DDT is equally effective against such species as *Culex pipiens* which often breed in tremendous numbers in highly polluted water. A residual spray in sheds and

other buildings where numbers of mosquitoes are found resting would be effective in reducing annoyance.

In New Jersey considerable experimentation has been done with various solutions, emulsions, and dusts against larvae of pest mosquitoes. Under New Jersey conditions there is little to be gained by the general use of DDT until better methods of application are developed or until more is known about the effect of the chemical on other life.

To get a residual toxicity from the use of DDT in larval mosquito control it has been necessary to use 1 per cent DDT in mosquito oil. Such an application results in a deposit of 2 to 5 lb. of DDT per acre, an amount at least four times as great as the ½ lb. per acre which kills fish. It is therefore evident that the material cannot be used where fish are present, and DDT sprays are not being recommended in New Jersey for general use against mosquito larvae. With additional experimentation it is possible that a satisfactory method of applying small quantities of DDT for larval control will be developed.

On sewer catch basins and in cesspools results with DDT for control of mosquito larvae are very promising. Here fish and aquatic insects are not found and larger quantities of DDT can be used safely, so long as sufficient DDT is not introduced from the catch basins or cesspools into waters where it might be hazardous.

In 1945 mosquito breeding was controlled in catch basins for 6 to 8 weeks by using 2½ and 4 per cent DDT in No. 2 fuel oil applied at the rate of about ½ pint to each basin. The constant flushing of basins by the heavy rains in July and August probably materially lessened the residual effect obtained. It is likely that in a drier season breeding would be prevented for a much longer period.

Adults were not repelled from such basins, for DDT is not a repellent, but large numbers of adults were never found resting in treated basins, though they were often abundant in those not treated. Extensive tests of DDT in catch basins are planned for the coming season in cooperation with several of the county mosquito commissions. The material will also be similarly used in cesspools where breeding of mosquitoes is heavy. It is suggested that a 4 or 5 per cent DDT solution in fuel oil would be effective for several weeks in both catch basins and cesspools. A considerable number of adults would be killed by spraying the walls of the basin or cesspool above water level.

Summary

The new insecticide DDT is a very effective material against many insects. Much remains to be learned about its effect on other life as well as on insects. Tests to date indicate that it is a valuable material particularly against flies and mosquitoes applied as a residual spray. At the present time the New Jersey Agricultural Experiment Station is recommending its use only on an experimental basis, and not for general use. Anyone using the material is cautioned to handle it with due care and to follow suggested precautions in its use.

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TIPS AND QUIPS

Sludge Wanted—In Florida

Recent correspondence with a broker of fertilizer materials revealed a most unusual situation in Florida, a demand for dried digested sludge greatly in excess of the demand!

This one broker disposed of 45 carloads during the period of April to October, 1946, mostly to first-time users. The reaction of the purchasers was highly favorable, and now the 1946 sources of supply—plants in Alabama and Ohio—are unable to guarantee sufficient 1947 shipments to fill the demand. Other sources of "high grade digested sludge" within a reasonable freight haul distance of Florida are sought, but with little success.

Sewage sludge is well-suited as a conditioner for the sandy soils that support Florida's citrus orchards. Several large cities in the state are about to build sewage treatment plants; it might be well for some of these cities to investigate the economics of drying facilities with a view toward furnishing the fertilizing elements that are so badly needed.

Operator Training in Texas

Almost everything worth while is done on a large scale in Texas, and the state certification and training program for the water and sewage works operators is no exception.

The annual operators' short school given in Texas is the mainspring of the training program, and has amazed many visitors from other parts of the country by its size and scope. The 29th of these schools, held at Texas A&M College on February 10–13, 1947, attracted 430 operators. Registration has consistently been in the range of 400 to 500 for the past several years.

A complex program is set up to give elementary courses to the Grade C operators (as classified in the state operators' certification law) and advanced training to those in the Grade A and Grade B classes. The 1947 short school offered 33 sessions, about a third of them being general ones for water and sewage operators of all grades. Lectures and discussion leaders are leading college and university personnel, consulting engineers, operators and municipal officials.

To supplement the annual short school, there are 26 regional associations in the state which hold regular meetings in the form of classes given by instructors of the Texas A&M College Industrial Extension Service. Moreover, special manuals have been developed on water works and on sewage works operation. The *Manual for Sewage Plant Operators,* a 435-page book including 27 chapters (see review in this issue), was made available for the first time at the 1947 short school. This manual will be useful as an instruction text and as a practical reference.

V. M. Ehlers, state sanitary engineer and originator of the Texas training and certification program for operators, flattered us on the occasion of our last visit by asking for suggestions as to how the short school might be improved. We could not offer a single one!

A New Filter Cloth

Sol Seid, Superintendent of the sewage treatment plant at New Brunswick, N. J., has been experimenting recently with a new type of cloth at the vacuum filters used for sludge dewatering. The new cloth is made of a synthetic fiber which is resistant to chemical action and mechanical abrasion. It is a lint-free material that passes liquids freely and does not plug easily, and is said to be unaffected by changes in temperature.

The new fabric is still in operation on a lime treated sludge after 500 hours of service, whereas the cloth formerly used had an average life of only 70 hours. The cost of the new fabric, based on service life, is proving to be less than 10 per cent of the cost of the material used before.

The name of the supplier of this promising vacuum filter medium will be furnished on request.

A Use for the Water Hyacinth?

Operators residing in Southeastern U. S. will be glad to learn that the water hyacinth has at last been found to have a desirable characteristic. Sir Albert Howard, in a paper presented before The Institute of Sewage Purification (England), reports the finding from studies in South Africa that these plants have a remarkable ability to remove dissolved salts from polluted water.

A comparison was made of the composition of plants grown in polluted river water and of others grown in the same water plus the salts used in water culture. In just 14 days the nitrogen content increased from 1.42 to 2.23 per cent, phosphoric oxide (P_2O_5) from 2.0 to 8.0 per cent, and the potash from 7.4 to 11.6 per cent. If large-scale tests support these preliminary findings, it is suggested that such water plants might be used as the last step in recovering fertilizing elements from sewage, while at the same time ridding the stream water of objectionable compounds.

The author asks and answers the $64 question as follows:

"What are we to do with the crop of water plants? This depends on the species and on the freedom from harmful bacteria of the water in which they are grown. The obvious methods is to compost them with dried sewage sludge and then to sell the compost. Later, when mankind frees itself from the thraldom imposed by fear of disease, they might even be used as food."

Tumbleweed Trouble

Discussing the operation of trickling filters in a Grade A and B operator's session at the 1947 Texas short school, City Sanitary Engineer J. A. Stanley, Jr., of Lubbock, described an interesting and unusual problem. The high rate trickling filter of the Lubbock plant seems to be a most effective tumbleweed trap, so effective in fact that this nomadic shrubbery gathers on the filter (when wetted) to the extent that the distributor arms are obstructed.

The difficulty was overcome by the provision of a portable fence that can be rotated about the filter according to the direction of the wind.

Sludge Makes the Greens Greener

The fertilizer manual, issued by the Federation as Manual of Practice No. 2, is finding a highly satisfying distribution among horticulturists, gardeners and others not directly engaged in the sewage works field. One order received recently from Mr. C. H. Gaskill, Jr., Vice-chairman of the Greens Committee at the Lincolnshire Country Club at Crete, Ill., was supplemented by the following unsolicited testimonial:

"We had prior to the summer of 1946 been bothered with 'brown patch' that we could not control, poor color, and practically a complete stoppage of growth on our greens during the hot months. A very poor physical condition exists and, while we could not rectify that last year, we tried feeding every two weeks with a prepared sludge, applied with a mechanical spreader at the rate of 10 lb. per 1,000 sq. ft. These applications were supplemental to the rather heavy spring and fall mineral fertilizations.

"Growth conditions, color and resistance to both disease and wear improved markedly. As a control, we treated one green with 20 lb. per 1,000 sq. ft. of air dried sludge that had been exposed to the weather the preceding winter. Results with this local material were identical with

those obtained with the commercial product.

"It was my intention to use only local material this year, but several references to the danger of too many weeds being introduced into our greens has caused me to postpone this switch until I make several more tests. Of course, the semi-annual application of a weak solution of 2, 4-d that we make minimizes this hazard."

Mr. Gaskill is to be complimented on his experimental procedure. He has been invited to keep us informed from time to time as to his further observations.

Air-Borne Public Relations

The city of Fort Worth, Texas, was quick to take advantage recently of the offer of a local radio station to make available weekly broadcast time for educational talks about various municipal services. One of these "spots" was assigned in February to W. S. Mahlie, Superintendent of the Fort Worth sewage treatment plant for a well-prepared dissertation on the facilities for which he is responsible.

Most, if not all radio stations, have time that can be made available for broadcasts that are in the public interest. Here is a fine "advertising" medium that may often be had only for the asking.

Engineer-Chemist "Feud" Goes International

One of the most refreshing bits of reading to come our way recently is the paper "The Aims and Methods of the Sewage Works Manager," presented by John H. Garner as the J. B. Croll Memorial Lecture at the 1946 Summer Conference of The Institute of Sewage Purification (England). It is regretted that space limitations make it impossible to reprint the paper here in its entirety.

The following extracts were selected because of the interesting manner in which Mr. Garner has dissected the qualifications of a successful sewage works manager, and because of the pertinence of his remarks to the good-natured conflict between engineers and chemists which has reared its head at several Federation meetings, with Don E. Bloodgood and C. C. Larson as the respective leaders of the two factions. Mr. Garner, a chemist by training, is presently Chief Inspector of the West Riding of Yorkshire Rivers Board.

"Many sewage works managers have entered upon that career through being induced to stay on after completing constructional work or installing mechanical plant; others have been appointed managers at works where it was obvious that the maintenance and operation of mechanical plant was a *sine qua non*. My opinion of those managers who have previously had engineering training and experience—whether civil, mechanical or electrical—is that they are generally of the very best type. Of necessity, engineers are men of action. They have to become skilled in the use of men and materials, as they have to produce something tangible as a result of their efforts. They have generally travelled about the country on various jobs, and the educational value of travel is well known. Those who eventually settle down as sewage works managers as a rule set to work to master the subject of sewage purification in regard to their particular works and, having made good there, then proceed to extend their experience and usually remain a long time on the same works. . . .

"During my experience I have seen several sewage works which had been allowed to degenerate into a dirty and almost derelict condition restored to efficiency, and capital expenditure on reconstruction avoided for many years, by the appointment of a mechanical engineer as manager. I have found that those engineers who have had a sound training can soon acquire enough knowledge of chemistry to carry out the usual routine tests for recording and controlling the operation of the various units of sewage purification plants. But without a good grounding in engineering methods, anyone appointed manager of a sewage works starts at a disadvantage, and if he does not aim at acquiring a good knowledge of that subject he will have a rough passage and probably land himself on the rocks.

"By this time the engineers will, no doubt, be thinking themselves the salt of the earth. A common failing, however, among sewage engineers is that, in tackling purification process difficulties and troubles, they do not aim at removing the root cause but make barnaclite additions to works and plant, resulting in unnecessary elaboration and complication of operation.

"Good engineering practice in sewage purification is simplicity in design and robustness of construction, and scientific advice should be obtained where chemical or biological methods are concerned.

"As in the case of engineers, a number of chemists have risen eventually to the rank of sewage works manager. The influx of chemists into the field of sewage purification followed largely on the work of the last Royal Commission on Sewage Disposal, and there has since been a gradual increase in the number employed. Some have been appointed as qualified chemists, knowing something of the nature of the work involved, but others have commenced work as junior laboratory assistants, knowing little or nothing of the duties or where the appointment could lead, until the manager taught and encouraged them to take up sewage purification as a career.

"It will be obvious that chemistry in itself is only a secondary qualification for sewage works management, and of recent years there has probably been a tendency to overestimate the importance of chemistry in sewage purification. The opinion has been expressed that the mental make-up of a chemist does not necessarily make him a good manager, and that a chemist, like 'Just William,' can become a menace to the community, unless kept within bounds.

"Too often chemists seem to experiment and experiment without being able to make a decision; in fact such chemists may be termed men of delayed action. They remind one of the motorist who never can make up his mind to buy a new car for fear a later model may soon come on the market. He tinkers with the old one, has troubles, breakdowns, incurs great expense, and is finally left with a very decrepit and unreliable machine. One should have the courage to make up one's mind to adopt the best practicable and available methods, and to operate them economically and efficiently for a reasonable length of time.

"It may be that the training of a chemist tends to make his mind too analytical and introspective, instead of synthetical and circumspective. Without in any way wishing to disparage chemist-managers, I would say: 'Lay that test-tube down! Get outside yourselves and the lab too. Spend more time on the works. Be satisfied to concentrate on nitrates until you have acquired a good theoretical and practical knowledge of engineering or, perhaps in this case, I had better say *chemical* engineering.' Above all, a chemist-manager should be able to write his reports in non-technical language and to translate the results of small scale experiments to working practice.

"I have no wish to make the chemists appear down-trodden; my observations in regard to them may seem rather severe but, after all, I am speaking from personal experience, having long since laid the test tube down.

"Good engineers and good chemists are usually men of high intelligence, but not all men of high intelligence are necessarily good engineers or good chemists. Whether the biologists will ultimately oust all others remains to be seen. They are certainly appearing on the scene, probing about and doing some interesting and useful work.

"A competent sewage works manager must be something of an *all-rounder,* and probably the majority of the members of this Institute realize that it should be their aim to come within that category, and that they should adopt methods which will ensure their doing so.

"Before concluding, may I be allowed to quote that 'to achieve complete happiness, one needs an interest other than one's work, so that by mutual reaction each interest is fanned to a greater heat of enjoyment.' To my mind there are few occupations which present such unique opportunities as sewage works management for finding an interest outside one's work. . . ."

Another interesting revelation in Mr. Garner's paper is that certification of operators (or managers) was initiated in England in 1913, and that "mention was made of the necessity of an examination to establish for sewage works managers a minimum standard of knowledge and proficiency" in 1902.

Editorials

FSWA OBLIGATIONS TO SUPERINTENDENTS OF SEWERS

The superintendent of the bureau of sewers of a large Midwestern city wrote us recently to inquire as to what the Federation offers those of the field who are interested primarily in the design, construction and maintenance of sewage collection systems, but who are not directly concerned with sewage treatment. Some of the facts presented in response to this query may be discussed to advantage here, for it is apparent that the present membership of the Federation does not include nearly as many sewer system superintendents as it should. The Federation is definitely "delivering the goods" for such personnel—both in quantity and quality—but somehow these contributions have been de-emphasized by their presentation with material on sewage treatment, industrial wastes and stream pollution.

An examination of the content of the JOURNAL for the last two years shows that there were many good papers on problems of sewage collection. Typical examples are the papers by Cranch on "lost" sewer location, Brown on sewer maintenance, planning and records, Pomeroy on sewer ventilation, Eisner on sewer construction, MacNicol on house sewer installation and maintenance, McLoughlin on infiltration studies, Palmer on control of sewer usage, Fishbeck on sewer regulators, Camp on sewer design, Pomeroy-Bowlus on sulfide control and Lea on pumping station design and maintenance. Many other papers published in the 1945–46 volumes of the JOURNAL are pertinent both to sewers and to treatment plants; the several papers dealing with the potentialities of household garbage grinders, those dealing generally with maintenance of structures and equipment, and those pertaining to safety hazards are illustrative.

Then there is the manual of practice program of the Federation's Committee on Sewage Works Practice, which is devoting a generous share of its effort to subjects of interest to those responsible for sewer systems. First, the "safety manual," published in 1945, is certainly in this category. Several hundred copies have been purchased for the instruction and reference of sewer maintenance crews. Of the eight manuals now in preparation, two others—the one on sewer maintenance and the one dealing with ordinances for the control of the usage of public sewers—deal with fundamental problems of sewage collection. The manuals on sewage works accounting and on sewage chlorination should also be of value to those concerned only with sewage collection systems.

It must be admitted that the programs of Federation meetings and those of its Member Associations are usually deficient in papers on sewer system problems. The reason for this may be that there is either no great demand for such topics or that there is a dearth of authoritative sources of material. We incline toward the latter explanation, and suggest that the solution entails a careful seeking out of competent authors with invitations for them to participate in programs. This will result in more extensive reference literature as well. Program committees will please take note!

Where the sewage collection and treatment functions are under separate supervision, as is the case in most

large cities, there appears to be somewhat more willingness on the part of treatment plant personnel to interest themselves in the sewer system than there is for sewer system personnel to become informed on the sewage treatment plant. This is a natural situation because the character of the sewage received for treatment at the plant is affected greatly by the manner in which the sewer system is operated and maintained. It will clearly be advantageous to the municipality if each department is thoroughly acquainted with the problems of the other. Such understanding and cooperation must be developed first at the local level by the supervisory personnel of the two departments; they would be furthered by joint participation in the professional activities of the Federation.

The advancement of knowledge pertaining to the nature, collection, treatment and disposal of sewage and industrial wastes is a basic objective of the Federation. There is consciousness of the obligation to serve those engaged only in the sewage collection functions and a sincere effort is being made to do so. Much more can be done, however, but only if (1) more superintendents of sewers can be interested in membership and (2) if they are invited and urged to participate in writing papers for delivery at meetings and for publication, and to take part in committee activities.

PROGRESS IN STANDARD METHODS OF ANALYSIS

The Ninth Edition of *Standard Methods for the Examination of Water and Sewage* has at long last made its appearance. Produced in the most trying of all periods and beset by many obstacles, the new edition brings credit to the organizations which collaborated in its publication, as well as to Dr. George E. Symons, who bore the brunt of the editorial detail. The Federation has no publisher's interest in the new edition but, as in the case of the two preceding editions, its Committee on Standard Methods of Sewage and Industrial Wastes Analysis has contributed the entire section on sewage methods. Dr. W. D. Hatfield has been chairman of this committee since 1931.

Although offered as "standard" methods, some of the analytical procedures contained in the new edition are in controversy and are already undergoing revision. This condition will always exist, however, because no method of analysis will ever reach such a state of perfection that it can not be improved upon. Realizing this fact, Dr. Hatfield's committee is now planning a comprehensive study of the limits of accuracy of all determinations presently used in analyzing sewage and industrial wastes, as a preface to intensive development of new and improved methods.

An application has been filed for a research grant from the National Institute of Health which, if approved, would advance the progress of this work by many years. The methods in use today have been almost entirely developed through voluntary contributions of effort and facilities.

W. H. W.

Proceedings of Member Associations

NORTH CAROLINA SEWAGE WORKS ASSOCIATION

26th Annual Meeting

Raleigh, North Carolina, November 18–20, 1946

The 26th Annual Joint Conference of the North Carolina Sewage Works Association and the North Carolina Section of the American Water Works Association was held at the Carolina Hotel in Raleigh, N. C., on November 18–20, 1946. A total of 237 members and guests were registered.

The meeting was called to order by L. I. Lassiter, Section Chairman, and an address of welcome was extended by Hon. Graham H. Andrews, Mayor of Raleigh, who stressed the importance of pure and adequate water supplies for any municipality as well as the necessity for a well managed plant.

The technical program was opened with E. D. Burchard of the U. S. Geological Survey presenting an informative paper entitled "Twenty Years of Stream Flow Measurement in North Carolina." Grover H. Jones, City Attorney of High Point led a thought provoking discussion on the legal responsibilities of municipal water and sewage departments.

The afternoon session was opened with the technicolor movie, "Clean Waters," shown through the courtesy of the General Electric Company. The remainder of the afternoon was devoted to round table discussions led by J. A. English and R. W. Luther.

The November 19th session was opened with a business meeting at which the following officers were elected to serve during 1946–47:

Chairman: J. A. English, Salisbury
Vice-Chairman: W. M. Franklin, Charlotte
Secretary-Treasurer: George S. Moore, Albemarle

Following the business meeting L. L. Hedgepeth of the Pennsylvania Salt Manufacturing Company presented the paper "Use—Not Abuse of Streams," an approach to industrial wastes pollution abatement.

At the Honorary Luncheon for national officers and guests, W. R. LaDue, President of AWWA spoke on "The Personnel Equation in Water Works." Representing the Federation of Sewage Works Associations, President F. S. Friel addressed the assembly on "The Aims and Objects of the Federation."

The Armco Drainage and Metal Products Company of Raleigh presented an interesting movie on the construction and coating of steel pipe. This was followed by round table discussions on plant operation led by W. M. Franklin and system maintenance led by C. W. Mengel.

The Annual Banquet and Dance was held in the Ballroom of the Carolina Hotel, with T. S. Johnson of Raleigh as toastmaster. Max D. Saunders of Chapel Hill was awarded the Maffitt Membership Cup for having obtained the most new members for the North Carolina Section of AWWA during the year. The George Warren Fuller Award was presented to McKean Moffitt of Wilmington, N. C., for the faithful and ingenious services he has rendered the North Carolina Section AWWA.

Following the presentation of the awards, Chancellor R. B. House of the University of North Carolina gave a most interesting and humorous address.

The session on the morning of the 20th was opened with a movie, "Concrete Facts," shown through the courtesy of the Master Builders Company of Cleveland, Ohio. Everett M. Jones of the Simplex Valve and Meter Company of Philadelphia spoke on the material supply situation, and gave little hope for the possibilities of immediate material deliveries.

A. M. Boehm, Engineer of the Worthington Pump and Machinery Corporation presented a paper on "Utilization of Sludge Gas for Power."

Immediately thereafter the meeting was adjourned to meet again November 10–12, 1947 in Greensboro, N. C.

GEO. S. MOORE,
Secretary-Treasurer

OKLAHOMA WATER AND SEWAGE CONFERENCE

20th Annual Meeting

Stillwater, Oklahoma, January 27–31, 1947

The 1947 Annual Meeting of the Oklahoma Water and Sewage Conference was held at Oklahoma A. and M. College at Stillwater on January 29, 1947, as a highlight of the 20th Water and Sewage Short Course. Total registration for the meeting and short course was 71.

The technical program consisted of the series of lectures making up the short course. These lectures covered practical hydraulics, operation and maintenance of sewage and water works processes and equipment, public relations, job training and sanitary chemistry. Laboratory sessions were held to supplement the lectures on water and sewage chemistry. Addresses on "Recent Developments in Sewage Treatment," by FSWA Vice-President George S. Russell and on "Recent Developments in Water Purification," by W. Scott Johnson of the Missouri Department of Public Health, were special features of the technical program.

Evening functions included a smoker and entertainment on January 27 and the Annual Conference Dinner on January 29. The speaker at the latter event was Dr. Morris M. Blair, Professor of Economics at A. and M. College, whose topic was "Employment, Wages and Cost of Living in 1947." Mr. Russell also spoke during this program, making the formal presentation of the $100 FSWA membership prize that was won by the Conference in 1946 when it recorded a 230 per cent increase in the membership of its Sewage Works Section.

At the business meeting on January 29, the Conference considered certain amendments to its constitution and by-laws, the matter being left for further study by the Executive Committee before submission to the membership for letter ballot. Officers elected to serve for the year 1947–48 were:

President—R. O. Williams, Foss
Vice-President—C. E. Moutrey, Tulsa
Secretary-Treasurer—H. J. Darcey, Oklahoma City
FSWA Director—Frank Taylor, Oklahoma City

The new Executive Committee, in its organization meeting, adopted the following five-point program as its objective for the coming year:

1. To encourage and promote district meetings.
2. To increase membership in the Conference, in the FSWA and in the AWWA.
3. To publish a conference bulletin and newsletter.
4. To encourage a licensing program.
5. To promote attendance at the annual short course.

H. J. DARCEY,
Secretary-Treasurer

TEXAS SEWAGE WORKS SECTION

1947 Annual Meeting

College Station, Texas, February 12, 1947

The Annual Business Meeting of the Texas Sewage Works Section of the Texas Water Works and Sewerage Short School was held on February 12, 1947, as a part of the 29th annual operators' school to be held at A. and M. College, College Station, Texas. Vice-Chairman J. H. Sorrels presided in the absence of Chairman L. C. Billings.

The report of the Certification Committee was presented by Chairman E. J. M. Berg. Actions were taken to establish the amount of credit that would be allowed toward the various classes of certificates for short school attendance, correspondence courses and for attendance of the field courses offered on chlorinator maintenance and repair.

The Committee on Remuneration of Sewage Works Operators reported through Chairman Tom Green, and action was taken to direct publication of at least a summary of the data in the short school *Proceedings*. The committee was commended for its services.

The new Manual of Sewage Plant Operation, published by the Section for use in short course of instruction of operators was presented and was enthusiastically received. The committee, editors and authors who participated in preparing the manual were formally commended by the adoption of a resolution of appreciation.

Mr. Joe A. Stanley was appointed chairman of a new Committee on Membership and Publicity. Officers elected to serve for the year 1947–48 were: J. H. Sorrels, College Station, as Chairman; Tom Green, Austin, as Vice-Chairman; and V. M. Ehlers, Austin, as Secretary-Treasurer.

The technical program offered by the Texas Water Works and Sewerage Short School was complete and diversified. This annual course of practical instruction is probably the most comprehensive one presented in the U. S., and represents a major element in the operators' certification program that was established by the Texas Legislature in 1945. The total registration this year was 430.

The opening day comprised general sessions at which short school President Joe B. Winston presided. The morning session included an address of welcome by President Gibb Gilchrist of Texas A. and M. College; a response by Mr. Winston; an address "The Role of Research in Water and Sewage Treatment," by Dr. F. E. Giesecke, Consulting Engineer, New Braunfels, Texas; and a discussion of the latter paper by V. M. Ehlers, Director of the Sanitary Engineering Bureau of the Texas State Department of Health.

The evening session on February 9 was a joint meeting of the regional water and sewage works associations. The theme of this program was "Community Responsibility and Public Relations," which was discussed from the standpoint of the water and sewage fields by AWWA President-Elect N. T. Veatch of Kansas City, Mo., and FSWA Executive Secretary W. H. Wisely.

The short course lecture program was sectionalized to afford water and sewage classes for each of the three grades of operators as provided for under the state certification law. Each topic was opened with a short paper by an assigned leader, who then conducted a question and answer forum. Participation in these discussions was comprehensive and informative.

Another major general session was the Annual Short School Banquet on February 12, at which the main speakers were State Representative Roger

Q. Evans and George Nokes. Mr. Evans stressed the importance of public education in regard to the value of water and sewage services in the community. Mr. Nokes spoke in behalf of a bill before the Legislature that would provide adequate funds for administering the new certification law. Annual awards made at the banquet included trophies and plaques to the city of Henderson, for the most attractive water works; to the city of Carthage for completing the most comprehensive improvement to its water system; to Rodd Field (U. S. Naval Air Station at Corpus Christi) for the best average effluent from a sewage treatment plant; and to the city of West University for having completed the most extensive sewage works improvements. Special awards included a $100 U. S. Saving Bond to Mrs. Earl R. Goodwin, in recognition of her services for the past 15 years as Assistant Secretary-Treasurer of the Short School; an attendance award, a plaque, to the Cap Rock Water and Sewerage Association; and Honorary Life Memberships to J. P. Winder of Dallas and to Prof. S. R. Wright of A. & M. College.

MRS. EARL R. GOODWIN,
Asst. Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New England Sewage Works Assn. New York State Sewage Works Assn.	Joint Meeting — Hotel Ten Eyck, Albany, N.Y.	May 26–27
Florida Sewage Works Assn.	University of Florida, Gainesville, Fla.	June 9–14
Central States Sewage Works Assn.	Spalding Hotel, Duluth, Minn.	June 20–21
Federation of Sewage Works Assns.	**San Francisco, Calif.**	**July 21–24**
California Sewage Works Assn.	San Francisco, Calif.	July 21–24
Pennsylvania Sewage Works Assn.	Electrical Engineering Bldg., State College, Pa.	August
Georgia Sewage Works Assn.	Ga. Institute of Technology, Atlanta, Ga.	Sept. 17–19
Kentucky-Tennessee Industrial Wastes & Sewage Works Assn.	Brown Hotel, Louisville, Ky.	Sept. 22–24
North Dakota Water and Sewage Works Conf.	Dacatoh Hotel, Grand Forks, N. D.	September
Ohio Conference on Sewage Treatment	Deshler-Wallick Hotel, Columbus, Ohio	Oct. 2– 3
Canadian Institute on Sewage and Sanitation	General Brock Hotel, Niagara Falls, Ont., Canada	Oct. 6– 8
Iowa Sewage Works Assn.	Cedar Rapids, Iowa	Oct. 9–10

Virginia Industrial Wastes and Sewage Works Assn.	Nansemond Hotel, Ocean View, Va.	Oct. 16–17
Missouri Water and Sewage Conf.	Jefferson City, Mo.	October
North Carolina Sewage Works Assn.	Sedgefield Inn, Greensboro, N. C.	Nov. 10–12

Twentieth Annual Meeting

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

San Francisco—July 21-24

in conjunction with

CALIFORNIA SEWAGE WORKS ASSOCIATION

Federation Affairs

NEW FSWA UNIT ORGANIZED IN VIRGINIA

Another important objective in the program of the Federation was achieved on March 4, 1947, when the Virginia Industrial Wastes and Sewage Works Association was created in a one-day organization meeting at the Hotel Roanoke, Roanoke, Va. The new association will take its place officially as the thirtieth Member Association of the Federation as soon as routine action can be taken by the Organization Committee and the Board of Control.

Preliminary organizational activity, carried on under the energetic leadership of D. R. Taylor, Assistant City Manager of Roanoke, resulted in the registration of 58 industrial, municipal and state officials for the charter meeting. Actively collaborating with Mr. Taylor were Richard Messer, Director of the Sanitary Engineering Division, State Department of Health and L. L. Hedgepeth, Technical Secretary of the State Water Control Commission.

Following the adoption of the constitution and by-laws, charter officers to serve for the year 1947–48 were elected as follows: President—R. W. Digges, Manager of the Hampton Roads Sanitary District Commission; Vice-President—B. L. Strother, DuPont Rayon Co., Richmond; Secretary-Treasurer—A. H. Paessler, Sanitary Engineer, Virginia State Water Control Commission. Mr. Hedgepeth was elected as FSWA director, to serve for a 3-year term.

Francis S. Friel, FSWA President, opened the scheduled program with an address on "Recent Progress of the Federation," in which he described some of the current activities and accomplishments of the international organization. He was followed by W. H. Wisely, Executive Secretary-Editor of the Federation, whose topic was "An Activity Program for a Regional Sewage Works Association." State Sanitary Engineer Richard Messer, reporting on the present status and recent activity in sewage works construction in Virginia, and L. H. Enslow, Editor of *Water and Sewage Works,* completed the morning program.

The afternoon program opened with a paper by President-elect R. W. Digges, on the subject "Effects of Sewage Pollution on Fresh Water." Mr. Digges approached his topic from the standpoint of the problem confronting the Hampton Roads Sanitary District. The final program contribution was an informative discussion on "The Cooperative Health and Sanitation Program of the Institute of Inter-American Affairs in Mexico," illustrated by a series of excellent color slides, and presented by Martin W. Johnson of the consulting engineering firm of Wiley and Wilson, Lynchburg, Va.

The enthusiasm prevailing at the charter meeting presages a vigorous and productive existence for this fledgling unit of the Federation. The people of Virginia are greatly indebted to Messrs. Taylor, Messer and Hedgepeth and to the others who brought about the creation of the new association, an agency which is certain to take a leading place in the cleansing and conservation of the waterways of the state.

SAN FRANCISCO CONVENTION DEVELOPMENTS

Preparations for the Twentieth Annual Meeting of the Federation, being staged in conjunction with the Nineteenth Annual Meeting of the California Sewage Works Association and concurrently with the 1947 Conference of the American Water Works Association, are now going forward in fine fashion. Although accurate data are not yet available, there is every indication that the total registration for the meetings will exceed 2,000.

Local Committees

Local arrangements at San Francisco are proceeding under the leadership of a joint committee headed by R. C. Kennedy and Blair I. Burnson as co-chairmen. Other joint subcommittees on arrangements are:

hotel arrangements—Nelson Eckart, chairman, with George Pracy, J. H. Peterson and Keeno Fraschina; entertainment—John B. Gill, chairman, with W. J. Orchard, G. T. Bowman and others to be selected; ladies entertainment—Mrs. Nelson Eckart, chairman, with Mesdames George Pracy, R. C. Kennedy, C. C. Kennedy, H. C. Vensano and R. G. Wadsworth; meeting room arrangements—J. W. Pratt, chairman, with J. T. Norgaard and J. H. Kimball. Special FSWA subcommittees on registration and finance are now being set up, with Harold L. May as chairman of the former and George White as chairman of the latter.

Time-Table of Events

The tentative time-table includes the following events and sessions:

Monday, July 21

10:00 A.M.—Registration and inspection of exhibits.
Board of Control business session.
Noon—Business Luncheon, California Sewage Works Association.
2:00 P.M.—Board of Control business session.
9:00 P.M.—Joint President's Reception and Dance.

Tuesday, July 22

9:30 A.M.—Convene Twentieth Annual Meeting.
Technical session.
2:00 P.M.—Joint technical session with AWWA.
8:30 P.M.—Joint Gala Entertainment.

Wednesday, July 23

9:30 A.M.—Technical session.
2:00 P.M.—Joint technical session with AWWA.
6:30 P.M.—Annual Federation Dinner.
9:00 P.M.—Joint FSWA and AWWA Dance.

Thursday, July 24

9:00 A.M.—Technical session.
1:30 P.M.—Technical session.
3:30 P.M.—Adjourn Twentieth Annual Meeting.
3:30 P.M.—Board of Control business session.

Technical Program Nears Completion

Program Chairman Gilcreas and his committee are in process of clearing final details on the technical program and, as usual, they are doing an outstanding job. Particularly significant sessions are those to be held jointly with AWWA on Tuesday and Wednesday afternoon. AWWA will be host at the Tuesday joint program, which will pertain to the general topic of "Ground Water Pollution." The Wednesday afternoon session, with the Federation as host, will follow the theme "Reclamation of Sewage Effluents." Speakers who have accepted assignments in this symposium include N. T. Veatch, Earnest Boyce, Abel Wolman, L. V. Wilcox and Dario Travaini; other contributors are yet to be selected.

The Tuesday morning session will open with a short general business meeting, followed by papers describing the sewage works improvements in development at San Francisco and Portland. The San Francisco project will be reported on by Clyde C. Kennedy; J. E. Stevens and H. L. Thompson will deliver a joint paper on the Portland project, which will be discussed by A. M. Rawn.

Stream pollution and industrial wastes papers will feature the Wednesday morning program. F. W. Kittrell, G. E. Symons, W. J. O'Connell, Jr., and W. T. Knowlton have accepted assignments here and at least one more paper is to be arranged.

The Thursday morning session will be devoted to the Annual Operators' Forum, this time arranged and presented by the California Sewage Works Association. Industrial waste problems, plant maintenance and operation kinks will be stressed. An abbreviated but important symposium on the B.O.D. determination will close the technical program on Thursday afternoon. Various studies and developments on this basic analytical tool will be reported by Harold B. Gotaas, W. F. Langelier, David H. Caldwell and R. G. Tyler.

Exhibits

The most comprehensive and elaborate manufacturers' exhibit ever to be staged is already assured by the unprecedented demand for display space. By early April, 95 companies had reserved 152 booths, requiring that some of the exhibits be set up outside of the huge Arena in the Civic Auditorium.

The Water and Sewage Works Manufacturers Association is bending every

effort toward the presentation of an exhibit that will be an outstanding feature of the concurrent meetings.

Entertainment

The social events are being planned to afford a variety of high quality entertainment. The President's Reception and Dance on Monday evening, which will be the opening general event of the AWWA and FSWA meetings, will serve admirably as a "Get together and get acquainted" function. Some form of home talent entertainment is tentatively planned.

The "Gala Entertainment" on Tuesday evening will be presented from the Arena stage. This program is being assembled under the personal supervision of W. J. Orchard—who has directed many of the most memorable entertainment events of AWWA and FSWA meetings in the past. This show is expected to climax all others.

On Wednesday evening, the Annual Federation Dinner will be followed by a dance which is to be opened jointly to Federation and AWWA registrants. It is probable that some entertainment will be offered at the dinner.

The general social program will be concluded on Thursday evening, when the Annual AWWA Dinner will be held.

Ladies' Entertainment

Arrangements are as yet in an early stage, but special ladies' entertainment events are tentatively scheduled for Tuesday, Wednesday and Thursday. One or more teas, a luncheon and bridge party, and special tours are being considered.

The final program will allow plenty of time for shopping and for sight-seeing.

Hotel and Transportation Reservations

All FSWA and AWWA members have been furnished with complete information and reservation forms for their use in making hotel and transportation reservations. Additional forms are available upon request to Federation headquarters.

All those planning to attend the concurrent meetings at San Francisco are urged to forward applications for reservations without delay.

F.S.W.A. 1947 CONFERENCE

San Francisco—July 21–24

SPECIAL TOURS

NEW YORK SPECIAL

En Route

Leave: New York, 1:25 P.M., Monday, July 14

Arrive: San Francisco, Sunday Morning, July 20

Stop-Overs: Rocky Mt. National Park, Salt Lake City, Boulder Dam, Las Vegas and Los Angeles

Return

Leave: San Francisco, 6:00 P.M., Friday, July 25

Arrive: New York, 8:30 A.M., Sunday, August 3

Stop-Overs: Portland, Victoria (Canada), Glacier National Park

Round trip from New York approximately $450 on all-expense tour basis. (Does not include expenses in San Francisco.)

For Information

E. A. Sigworth, Suite 1333, 230 Park Avenue, New York 17, N. Y.

DIXIE SPECIAL

En Route

Leave: New Orleans, 11:30 P.M., July 14

Arrive: San Francisco, 7:30 A.M., July 20

Stop-Overs: El Paso and Grand Canyon

Return

Leave: San Francisco, 9:00 P.M., July 25

Arrive: Kansas City, 8:10 A.M., July 30

Stop-Overs: Los Angeles, Boulder Dam, Salt Lake City, Denver (short time)

Round trip from New Orleans approximately $175 for rail and pullman. Cost of meals and sightseeing tours will be extra.

For Information

W. H. Weir, Atlanta, Ga.

Egmont S. Smith, Dallas, Tex.

A. P. Black, Gainesville, Fla.

Thomas L. Amiss, Shreveport, La.

Make Reservations Promptly

Reviews and Abstracts

Edited by

H. Gladys Swope *

Allegheny County Sanitary Authority,
4501 Center Avenue, Pittsburgh 13, Pa.

Sewage Disposal as a National Problem. By E. J. Hamlin. *The Surveyor,* 105, 919–922 (Nov. 29, 1946).

This paper by Mr. Hamlin is his inaugural address to the Institute of Sewage Purification as President of the Society. The paper deals with conditions in South Africa and stresses the need for a united effort and the consideration of South Africa's sewage disposal problems on a national scale.

In the past, sewage disposal has been regarded too narrowly as a local or, at best, a regional problem, and it is pointed out that an endeavor should be made to regard it as a national problem.

Several factors in South Africa are cited which make this point, especially as regards the end products of sewage disposal, clean water, fertilizer, and gas, and it is asked whether or not the best uses are made of these products. As regards sludge disposal, he says that whereas the most economical method from the local point of view may be to barge it to sea, from the national viewpoint, this method can be regarded as uneconomic. In his opinion, because of the tremendous soil conditioning properties of sludge, every pound of it should be put upon the land.

As to gas utilization, power generation may not be the best use for the gas. At one plant some 400,000 cu. ft. of gas per day are collected. The plant chemists produced formaldehyde from the gas and during the process found that acetylene could be produced. This led to the production of cyanide from sewage gas. This is of great significance in South Africa where cyanide is so essential to the gold mining industry. From the sewage gas of Johannesburg sufficient cyanide may eventually be manufactured to supply the entire gold mining industry.

The author cites some of the conditions in South Africa which affect materially the design of sewage works. There is a tremendous variation in rainfall. Over more than 60 per cent of the total area the rainfall is less than 15 in. per annum and there are some areas where it is less than 5 inches. On the other hand, there are areas where rainfall varies from 80 to 120 in. per year. In some areas storms occur in which 5½ in. fall in 24 hr., and in Johannesburg it is not unusual during every summer season to have rainfall intensities up to 12 in. per hour. Such conditions as these require separate storm and sanitary sewers.

At the Cydna plant yearly average flow is about 2.0 m.g.d. Storm water flowing down the valley past the works reaches an intensity rate of 6,000 m.g.d.

The amount of rainfall in some cases is so limited as to restrict construction of sewers and treatment works.

South Africa has a population of about 12½ millions, of which 2½ millions are Europeans. Population densities in urban areas are low, only 4 per acre in Johannesburg, for example. Thus the length of collecting sewers per capita is great and sewage is consequently in the sewers a long time before reaching treatment works, thereby becoming stale and difficult to handle.

Sewage disposal by dilution is not practised in South Africa because of the low flows in the rivers. A high quality effluent must be produced in the treatment works.

* It will be appreciated if Miss Swope is furnished all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

Annual evaporation ranges from 72 in. in Johannesburg to 90 in. in Kimberly. This facilitates drying sludge on open beds. On the other hand, the low oxygen content of the atmosphere at high altitudes makes activated sludge treatment expensive.

The author reviews work done by the South African Institute for Medical Research in connection with the purification afforded by various sewage treatment facilities as regards removals of worm ova cysts, and pathogenically dangerous bacteria. Samples were taken over an entire year from the five Johannesburg sewage works. The work established the fact that:

1. The cysts of *Entamoeba histolytica* and eggs of *Ascaris lumbricoides* (round worm), *Taenia saginata* (tape worm) and *Ankylestoma* (hook worm) are frequently present in Johannesburg raw sewage.
2. Cysts or eggs have been found in screened sewage, settled sewage, primary filter effluent and humus tank effluent, and also in the effluent from activated sludge plants.
3. In the samples examined, no eggs or cysts were found to have passed secondary sand filters or underdrained land filtration areas.

In 1945, eight cases of infantile paralysis occurred in an area draining to the Cydna sewage works. Monkeys injected with screened sewage, settled sewage, and humus tank effluent developed paralysis, whilst the monkey injected with secondary sand effluent did not. Five months after the last known case of paralysis was removed from the area, a repeat set of samples was taken with similar results.

The author feels that these experiments prove the value of secondary sand treatment for South African conditions.

The article contains a description of the Hamlin reversible sand filter which serves as a humus tank and sand filter combined.

Primary filter effluent is supplied to the filter by means of a central channel throughout the bed length. The channel weir is at the medium level. The filtered effluent is collected in two channels constructed below and adjacent to the supply channel.

By means of controls the bed can be drained down to medium level or below and then backwashed with effluent from another filter bed in which the water level is 3 in. higher than medium level. The operation can be reversed and the primary effluent fed from below.

This type of filter has been a great success in South Africa.

K. V. Hill

Purification of Waste Waters from Fruit and Vegetable Canneries. By D. Dickinson. *The Surveyor,* **105**, 1001–1004 (Dec. 27, 1946).

Experiments on lime treatment, with sedimentation, of fruit and vegetable cannery wastes, the purification of the settled wastes in shallow clinker-filled channels, and the filtration of the settled wastes with recirculation on trickling filters are discussed.

It was found that the addition of 4 lb. of lime per 1,000 gal. assisted greatly the purification of the wastes with sedimentation. Considerable experimental work was done to determine the correlation between the oxygen consumed reduction and the pH of the settled waste, in order to utilize the pH as a controlling factor. The conclusion reached was that, with a constant lime dosage, the percentage purification obtained by sedimentation is proportional to the strength of the crude waste, on which the pH of the tank effluent also depends. The ratio of percentage purification to pH of settled waste shows a maximum between pH 6.0 and 6.9, presumably the iso-electric point. The amount of lime added should, therefore, be varied so as to produce a tank effluent with a pH not less than 6.0, when a percentage reduction in the oxygen consumed value averaging 35 per cent of that of the waste may reasonably be expected.

In the experiments with clinker-filled channels, the channels were cut in the earth in a herringbone pattern to a total length of about 300 yards. The average width was 1 yd.. and the average depth 10 inches. Settled cannery wastes were passed through the channels at rates from 20,000 to 25,000 gal. per day over a 10-hr. working period. A considerable quantity of grayish slime developed on the clinker which contaminated the clinker and necessitated removal and replacement with fresh clinker. The average purification effected during a one-

year period of test was 8.3 per cent, with the percentage for any three-months' period varying from 5.4 to 13.1 per cent.

A filter was constructed for experimental purposes. The filter was 6 ft. in diameter and 6 ft. deep, filled with 1 to 1½-in. limestone. Waste was applied to the filter with a rotary distributor rotating at 2.1 r.p.m. Provision was made for adding filter effluent to settled waste to obtain various dilutions for recirculation.

During the experimental period, wastes were treated from the canning of carrots, potatoes, beet root, rhubarb, spinach, and broad beans.

Carrot waste was the first waste treated. There was no dilution of the waste. The effluent was recirculated 14 hr. at night and at weekends. For three weeks the volume of waste treated in 10 hr. was 53 gal. per cu. yd. at the rate of 127 gal. per cu. yd. per day. No growth appeared on the surface of the filter. The effluents during the day showed about 90 per cent reduction in B.O.D. Nitrites were produced during recirculation overnight, with little nitrate.

Treatment of beet canning waste was then tried, with the dosage rate halved. Within three weeks, the filter was covered with a slimy growth and ponded badly. B.O.D. reduction was greater than before. The nitrite and nitrate production was greater before filtration than after. Attempts to clear up the ponding by recirculation of effluent and dilution of the wastes treated being unsuccessful, the filter was inoculated with Achorutes larvae and left for about two weeks. The insects greatly reduced the surface growth.

The filter was put back into service treating potato waste at a dosing rate of 110 gal. per cu. yd. per day, using a dilution ratio of 2.9. There was a steady improvement in the quality of the effluent.

The next period was devoted to purification of beet root waste. The dosage rate was maintained at 110 gal. per cu. yd. per day, but the dilution ratio was reduced to 2.0. B.O.D. reductions were in excess of 96 per cent, with very good color removal.

During the above, the filter was doing useful work only for 10 hours. It was being reactivated during the remaining 14 hours by treating recirculated effluent. Recirculation of the effluent did not affect further purification. The function of the process was to recondition microbiological film on the filter medium and to prevent ponding.

During the progress of the work, some study was made of the effects of filtration on the bacterial content of the wastes. The results of these studies may be summarized by stating that the bacterial counts at 37° C. were reduced from 35 to over 99 per cent by the recirculation system of filtration.

The author concludes that the experimental results indicate that some of the most difficult cannery wastes can be treated satisfactorily by diluting the settled wastes with two to three volumes of effluent and applying the mixture to the filter at the rate of about 100 gal. per cu. yd. per day, provided the mixture is treated for only 10 hr. in each 24-hr. period. About 13 cu. yd. of filter medium were required to remove each pound of B.O.D. The most difficult waste to treat is that from potato canning. Carrot canning waste is easy to treat, with beet root waste the next most difficult. It is desirable to dilute the waste with a sufficient proportion of the filtered effluent to give a mixture having an average B.O.D. of about 200 parts per million.

K. V. Hill

Study of the Treatment of the Wastes from the Preparation of Coffee. By Robert K. Horton, Mario Pacheco and Manuel F. Santana. Paper presented at Second Inter-American Regional Conference of Sanitary Engineering. Caracas, Venezuela. Sept. 26 to Oct. 2, 1946. (Original Paper in Spanish.)

This is a report of work done on an unusual waste, common only to countries producing coffee and a problem only in those countries. The object of the study was to determine an economical method of preventing stream pollution, and, if possible, to recover water for re-use in El Salvador (Central America) where water is scarce during the coffee preparing season. Coffee wastes are of two kinds: depulping wastes, carrying outer pulp removed from green coffee beans; and fermentation water used to wash the coffee beans during the fermentation period and as a conveyor to the drying platforms. The latter comprises the larger volume.

The experimental plant is located at one of largest coffee plantations in El Salvador near the capital, which treats 500,000 pounds coffee per day. The pilot plant comprised a retention lagoon of 4,860 gal.; sedimentation tank (plain) of 425 gal.; a stone filter 16 sq. ft. in area and 6 ft. deep; a final detention tank of 306 gal.; and a 2 in. centrifugal pump driven by a gasoline engine. To develop colonies of bacteria in the filter, wastes were circulated through it daily for a month before the test began.

Process of treatment: The wastes were run into the sedimentation tank. When chemical precipitation was used, the coagulant was added in sedimentation tank and mixed by hand. The mixture then held for one hour in the sedimentation tank and then a predetermined volume (based on the filter loading selected and number of recirculations per hour) was siphoned in the detention tank.

Samples of filter effluent were taken at 2, 4 and 6 hr., but circulation through filter continued 12 to 16 hr. and sometimes 24 hr. longer. All samples were settled one-half hr. before analysis. The analyses made were 5-day B.O.D. at 20° C., pH; turbidity and total solids. The tests demonstrated that wastes vary in every coffee plant, both in concentration and extent of contaminating elements. There was no exact data on the amount of water used per unit of coffee but it varied between 100 and 260 gal. per 100 lb. coffee beans. Waste also varies hourly and are seasonal.

The tables show the results of the tests. Table I shows analyses of untreated fermentation water, based on 30 different samples, taken on different days throughout campaign. Table II shows analyses of samples on middle day of campaign, also composited samples of that day. The B.O.D. shows that daily wastes consist of small volume of high concentration and relatively large volume of low concentration. Table III is a résumé of analyses on depulping waters, based on 12 samples on different days in last half of campaign. Sampling hour always coincided with maximum work in depulping operation. Table IV shows analyses of mixture of fifty-fifty of each waste during last days of campaign.

TABLE I.—Characteristics of Fermentation Wash Water

	Min. p.p.m.	Max. p.p.m.	Mean p.p.m.
B.O.D. (5-day at 20° C.)	295	3,600	1,700
pH	4.1	5.5	4.5
Turbidity	250	4,000	1,750
Suspended Solids	235	2,385	900
Total Solids	885	3,140	2,100

TABLE II.—B.O.D. of Fermentation Water at Different Times during Washing Process

Sample No.	Time of Sampling	B.O.D. p.p.m.
1	Start of wash	1,310
2	3½ hr. after start, near peak of wash	2,820
3	6 hr. after start	98
4	End of wash (10 hr. after start)	35
5	Composite of samples taken every 15 min.	490

TABLE III.—Characteristics of Depulping Wastes

	Min. p.p.m.	Max. p.p.m.	Mean p.p.m.
B.O.D. (5-day at 20° C.)	3,280	15,000	9,400
pH	4.1	4.7	4.4
Turbidity	1,500	4,000	2,900
Suspended Solids	625	1,055	790
Total Solids	10,090	12,340	11,300

TABLE IV.—Characteristics of Combined Wastes. (50% Fermentation Water and 50% Depulping Wastes)

	Min. p.p.m.	Max. p.p.m.	Mean p.p.m.
B.O.D. (5-day at 20° C.)	2,500	8,000	4,250
pH	4.3	4.7	4.5
Turbidity	1,500	2,500	2,250
Suspended Solids	530	810	640
Total Solids	6,800	7,240	7,050

General results of study were: Biological treatment with recirculation through stone filters was effective. One hour sedimentation produced very little reduction in B.O.D., usually between 16 to 29 per cent. After preliminary seeding of filter, fermentation water circulated for 3 days to accustom filter organisms to the wastes.

TABLE V.—Treatment of Fermentation Water by Recirculation Through a Biological Filter

Filter Operating Conditions			B.O.D. of Settled Waste in p.p.m.	Per Cent Reduction in B.O.D. After Treatment for			Turb. of Settled Waste in p.p.m.	Per Cent Reduction in Turbidity After Treatment for		
Rate of Recirculation in M.G.A.D.	No. Recirculations per Hr.	Vol. in Gal.		2 Hr.	4 Hr.	6 Hr.		2 Hr.	4 Hr.	6 Hr.
20	2	153	2,000	77.5	86.0	90.5	1,000	80	88	91
20	5	61	295	72.9	85.5	—	350	97	97	—
40	5	122	1,990	53.7	63.6	75.7	1,500	40	53	79
40	8	77	448	72.8	86.4	91.0	250	84	92	96
60	5	184	2,700	73.6	85.5	90.4	2,500	80	84	90
60	8	115	2,500	74.0	84.4	90.0*	2,000	70	78	85*
60	10	92	2,800	82.1	84.6	92.0	2,000	83	85	88
100	15	102	2,100	73.7	80.7	87.5*	200	78	87	93*

* Treatment for 5½ hours.

TABLE VI.—Chemical Precipitation of Fermentation Wash Water

Coagulant				pH	Per Cent Sludge After 1 Hr. Settling
Name	Dosage p.p.m.	Name	Dosage p.p.m.		
Aluminum Sulfate	100	Lime	100	6.3	100
Aluminum Sulfate	3,000	Lime	600	7.8	98
Ferric Chloride	50	Lime	25	5.1	100
Ferric Chloride	500	Lime	500	9.6*	99
Copperas	200	Lime	100	4.5	100
Copperas	600	Lime	600	6.7	100
Lime	500	—	—	9.6*	100
Lime	5,000	—	—	9.6*	98

* pH greater than 9.6.

Table V shows total of 8 tests on fermentation water; Table X on depulping wastes. Loading on filter ranged between 20 and 100 m.g.a.d. Number of recirculations between 2 and 15 per hour. Reduction of B.O.D. varied between 53.7 and 82.1 per cent after 2 hours sedimentation; 63.6 to 86.4 after 4 hours and 75.7 to 92.0 per cent after 6 hours. Reduction of 96.0 per cent obtained in 6 hours with recirculation of 10 volumes of waste per hour at loading of 60 m.g.a.d.

There was no evidence of filter clogging during the tests but as wastes contain much mucilaginous matter clogging may have resulted if tests had been continued for some weeks. The longest period of filter operation during tests was a little over one week.

Table VI shows results of chemical precipitation, with chemicals employed. Lime used as pH correctant in all cases. An insoluble floc formed by all coagulants, with resultant slow settling surface mats. Lesser quantities coagulant shown in the table are minimum doses which produced good coagulation; the larger quantity is the maximum used during test. Lime produced results equal with the others. Clay was added as weight but produced no better results than lime alone.

TABLE VIII.—Chemical Precipitation of Fermentation Wash Water After Extended Fermentation Without pH Adjustment

Sample of Fermented Wastes Treated with Lime			
Days after Taking Sample	Amount of Lime Used p.p.m.	Per Cent Sludge After 1 Hr. Settling	Turbidity of Supernatant Liquor
0	sample collected		—
1	—	—	—
2	—	—	—
3	500	3.2	80
	1,000	11.0	60
4	500	4.0	70
	1,000	5.7	60

TABLE IX.—Chemical Precipitation of Fermentation Wash Water After Extended Fermentation with pH Adjustment

Days After Taking Sample	Lime Required for Neutralization r.p.m.	Total Lime Added for Neutralization p.p.m.	Sample of Fermented Waste Treated with Excess Lime			
			Lime for Excess Treatment p.p.m.	Total Amount Lime Used p.p.m.	Per Cent Sludge After 1 Hr.	Turbidity of Supernatant p.p.m.
0	sample collected					
1	344					
2	0	344				
3	119	463				
4	425	888				
5	106	994				
6	7	1,001				
7	37	1,038	1,100	2,138	100	—
8	0	1,038	500	1,538	4.9	30
			1,000	2,038	7.0	20

TABLE X.—Treatment of Depulping Wastes by Recirculation Through a Biological Filter

Filter Operating Conditions			B.O.D. (5-day) in p.p.m.				Per Cent Reduction in B.O.D. After Treatment for		
Rate of Recirculation in M.G.A.D.	No. Recirculations per Hour	Vol. in Gal.	Settled Waste	After Treatment for					
				2 Hr.	4 Hr.	6 Hr.	2 Hr.	4 Hr.	6 Hr.
20	5	61	15,000	4,680	4,350	3,300	68.8	71.1	78.0
40	5	122	9,800	4,150	2,520	1,200	57.6	74.3	87.8
40	8	77	4,900	1,530	1,325	1,245*	68.7	72.9	74.5*
40	10	61	3,280	2,200	1,335	1,170	32.9	59.3	64.4
100	15	102	15,000	5,120	5,000	—	65.8	66.7	—

* Treatment for 5 hours.

TABLE XII.—Treatment of Combined Waste by Recirculation Through a Biological Filter

Filter Operating Conditions			B.O.D. (5-day) in p.p.m.				Per Cent Reduction in B.O.D. After Treatment for		
Rate of Recirculation in M.G.A.D.	No. Recirculations per Hour	Vol. in Gal.	Settled Waste	After Treatment for					
				2 Hr.	4 Hr.	6 Hr.	2 Hr.	4 Hr.	6 Hr.
20	5	61	2,200	600	550	250	72.7	75.0	88.6
40	5	122	2,450	920	650	420*	62.4	73.5	82.9*
40	8	77	2,800	950	700	400	66.1	75.0	85.7
40	10	61	2,951	900	700	450*	69.5	76.3	84.7*
60	5	184	2,850	960	690	380*	66.4	75.8	86.7*

* Treatment for 5½ hours.

The tests proved that biological filters with high rates of application and recirculation was the best method, but efficiency was less on depulping wastes than on fermentation water. Table XII shows results of 5 tests on combined wastes, with various loadings and recirculations. Conclusion: high rate filters with recirculation possesses definite advantages over "standard rate" filter and other biological meth-

ods. This permits smaller filters, lower cost construction, automatic cleaning, and better able to withstand rapid changes in character and concentration of wastes. This latter is of prime importance in treating industrial wastes, especially food wastes, textile and distillery wastes. High rate filters require less skilled attention. Wastes should be separated and only the strongest treated. Re-use of wash water reduces volume but increases strength of final wastes.

The use of effluent for irrigation is proposed. Results indicate that wastes with small quantities of solids are not toxic to vegetable life, but more studies are required to determine effects on soil in use. Investigation of treatment of these wastes with sewage should be made.

E. B. BESSELIEVRE

Purification of Sewage at F. D. Funes Hospital, Province of Cordoba, Argentine. By CARLOS S. CARRIGUE AND OMAR L. VERNA. *Revista de la Administraction del Agua,* No. 110, pp. 113–125 (August, 1946).

The article describes a plant comprising Imhoff tanks and intermittant sand filters for a tuberculosis hospital, design population of 800. The original plant contained septic tanks and 12 wells, 10 ft. diam. × 25 ft. deep. The ground was not suitable for absorption so the plant was abandoned. The new plant was designed for a flow of 84,480 g.p.d. at 106 g.p.c.d. average and a maximum of twice the average.

The main sewer was reinforced concrete, 62 in. diam., 2,132 ft. long with a velocity of 1.64 ft./sec.

A high grade effluent was required as it discharged into the Rio Cosquin which had a small flow and there were towns downstream. The treatment had to be adapted to climatic conditions; the mean temperature being 60.4° F. and the annual rainfall 25.56 inches.

The treatment plant was also located 0.6 mile from the hospital and 0.3 mile from a small town.

The plant consists of hand raked bar screens with 1 in. free spacing, the screenings being raked onto a perforated metal plate for draining after which they are buried. There are two Imhoff tanks with rectangular reinforced concrete sedimentation compartments, 5.1 ft. deep and slope of 1.5 to 1, with a detention period of 1.5 hours. There are two bottom slots each 9 in. wide. The gas slots are 6.58 in. on each side. The channels and stop gates are arranged for cut out of either unit. There are concrete vanes projecting downward at the entrance and exit to the sedimentation compartment and 12 in. under the surface which catch floating solids and prevent their passage to the sand filters.

The digestion compartment is designed for 1.8 cu. ft. per capita, each with two hoppers with slopes 1.7 to 1, the bottom being 16.4 ft. from the liquid level. There are holes in the walls between hoppers to equalize sludge and load. There is a scum compartment on each side of the sedimentation compartment with free area equal to 40 per cent of the horizontal area of the sedimentation compartment. This large area was deliberate in an effort to eliminate foaming. The scum slot sides are elevated 19.5 in. above the top tank to prevent slopping over. The volume of the scum compartment is fixed at 50 per cent of the volume of the digestion compartment.

The sludge is discharged by hydrostatic head into measuring boxes and thence to sand drying beds.

The effluent is run onto intermittent sand filters. As there is no natural sand nearby the cost for sand filters is high. The sand is graded according to the norms established by the committee on filtering material of the ASCE, 1937. There are 8 filters and these are each dosed once per day. The dosage rate is 79,060 g.p.a.d. The total area of the sand filters is 1.06 acres, each unit being 5,400 sq. ft. The dosing tank holds 10,560 gal. and is divided into 8 sections, one to each filter. The sand filters are in batteries of 4 with walks in between. The distribution of the effluent is by open troughs onto semicircular concrete splash pads. The drains are open joint pipe or are covered with gravel. The filter surface is graded for perfect distribution.

The dried sludge mat from the filters is estimated at 5,250 cu. ft. annually. The area of the sludge drying beds is 1.0 sq. ft. per capita. There are ideal drying conditions as there are only 60 days of rain per year. Sludge is applied to beds 7.8 in.

deep. There is a central covered drain and the drainage is returned to the Imhoff tanks.

Chlorination of the effluent is proposed using hypochlorinators.

A small building houses the chlorinators, material stores, wardrobes and bath for personnel. There is a house for the operator 500 ft. away containing two rooms and an office.

The article is illustrated with sketches and cuts of plans.

E. B. BESSELIEVRE

Twenty Years' Experience with the Dissolved Oxygen Absorption Test in China. By W. E. ABBOTT. *J. Society of Chemical Industry* (Brit.), **65**, No. 3, 87–90 (March, 1946).

The deoxygenation rate of diluted samples of sewage and effluents was followed and at intervals the different forms of nitrogen were determined. The two stages of oxidation were well defined and in a number of cases a lag period before the carbonaceous stage was evident.

A good agreement between calculated and observed values was obtained by the use of a modified formula

$$\log \frac{L}{L - X_t} = K\,(t - T)$$

where L = total carbonaceous absorption
X_t = absorption time in t days
T = constant
K = constant time (days)

The calculations were made on the basis of observed results up to 5 days, after which nitrification exerted an influence.

In adjusting the equation to the experimental data: "a tentative value of L was chosen from inspection of the absorption-time graph up to the commencement of nitrification. The corresponding values of $(L - X_t)$ were calculated and log $L/(L - X_t)$ was graphed against the time. If the points lay on a straight line the values of K and T were derived from its characteristics." If the points were on a curve then a lower value of L was adopted and the computation repeated.

In Table I are shown the facts as represented by the modified equation:

TABLE I.—Course of Absorption of a Sewage Sample

Incubation Days	Dissolved Oxygen Absorbed at 20° C. Parts per Million	
	Actual	Calculated
2	97	96
3	164	165
4	214	213
5	247	247
7	322	—

Calculated from $\log \frac{330}{330 - X_t} = 0.15\,(t - 1.0)$.

TABLE III.—Distribution of the Values of K at 20° C.

Value of K	Number of Cases		
	Raw and Settled Sewage	Centrifuged Sewage	Creeks and River Water
0.075–0.099	4	7	4
0.100–0.124	14	11	6
0.125–0.149	9	9	3
0.150–0.174	7	6	3
0.175–0.199	4	8	0
0.200–0.224	1	3	4
0.225–0.249	1	1	1
0.250–0.274	3	1	—
0.275–0.299	1	—	—

TABLE V.—Course of Absorption of a Sewage Sample at 11° C.

Time in Days	Dissolved Oxygen Absorption Parts per Million		
	Found	Calc. Eq. A	Calc. Eq. B
1	16.5	0.0	14.2
2	34.2	0.0	35.8
3	60.3	59.9	63.3
4	96.9	96.6	92.0
5	117.6	119.2	116.2
7	142.2	141.5	143.1

Eq. A $\log \frac{155}{155 - X_t} = 0.212\,(t - 2.0)$.

Eq. B $\log \frac{155\,(X_t + 18.0)}{155 - X_t} = 1.256 + 0.294t$.

"The simpler formulation of the modified monomolecular equation represents the data very well for the period from 3–7

days. On the other hand, the whole of the absorption up to the 7th day can be represented tolerably well by the equation

$$\log \frac{155\,(X_t + 18.0)}{155 - X_t} = 1.256 + 0.294t$$

This is an algebraic simplification of Fair's equation

$$\log \frac{L - \dfrac{X_t}{X_t}}{X_t + \dfrac{k_1}{k_2}} = \log \frac{k_2}{k_1} - (k_2 L + k_1)t \log e$$

when $k_1 = 0.0704$
$k_2 = 0.0039$
$L = 155.0$

As above L is the total carbonaceous absorption and X_t is the oxygen absorbed in t days."

The values of K and T varied considerably at any given temperature as indicated below.

The substitution of $(t - T)$ for t in the monomolecular equation takes into cognizance a period of accelerating absorption before the characteristic course of absorption is established. At temperatures above 25° C. the need for the correction had practically disappeared.

The course of the carbonaceous stage at constant temperature varies considerably. It is impossible to calculate the B.O.D. of a sample for any time from the known B.O.D. for a single period. There is no sharp demarcation between carbonaceous and nitrogenous stages. The duration of carbonaceous oxidation varied from 4 to 8 days (average 5½) in 45 cases after which nitrification also exerted its influence. As a rule the B.O.D. of the sample was independent of the dilution.

The B.O.D. determination gave high and variable results in the case of well-clarified activated sludge effluents unless the $NH_3 - N$ had been nearly all oxidized in the treatment. At times exceptionally good effluents gave B.O.D. values approaching those of the original raw sewage. To overcome this difficulty incubation periods of 2 and 5 days were used for a time. Raw sewage gave a ratio of 5:2-day B.O.D. of 1.9 and activated sludge effluents gave a ratio of 3.5. Below are given the percentage of samples falling in the different ratio groups:

Ratio	Percentage of Cases Falling in Group	
	Raw Sewage	Effluent
Under 2	4	3
2.00–2.99	75	25
3.00–3.99	17	36
4.00–4.99	—	9
5.00–5.99	—	15
6.00–6.99	4	3
7.00–7.99	—	6
Over 10.00	—	3

This method of assessing the purification was found generally satisfactory but at times the 2-day B.O.D. of sewage samples was low owing to a lag period, while the 5-day B.O.D. of the effluent was high owing to nitrification. As a compromise a 3-day period of incubation was adopted as standard retaining the 5-day period as a lesser standard. The percentage purification by using the 3-day incubation period is probably the greatest that can be obtained. In-

TABLE VI

Type Liquid	Incubation Temp.	Value of K			Ave. Value T (Days)	Cases
		Ave.	Max.	Min.		
Raw Sewage	20	.149	.290	.090	.40	43
Centrifuged Sewage	20	.143	.269	.085	.35	46
Creeks	20	.150	.246	.077	.15	13
River Water	20	.118	.152	.090	.22	8
Activated Sl. Eff. Shaken	20	.098	.100	.092	nil	5*
Activated Sl. Eff. Filtered	20	.165	.366	.100	.04	7*
Settled Sewage	37	.304	.430	.193	−.06	5

* The stage was too short for mathematical treatment in the great majority of cases.

cubation for one or two periods without determination of possible changes in the nitrogen compounds can never be wholly satisfactory.

An attempt was made to correlate *L* values at 20° C. and oxygen consumed from permanganate. The following results were obtained with raw sewage and activated sludge effluent:

$$\text{The Ratio } \frac{\text{L absorption}}{\text{permanganate absorption}}$$

	Ave. Ratio
Raw Sewage (Jan.–March)	4.8
Raw Sewage (April–June)	4.1
Raw Sewage (July–Sept.)	3.3
Raw Sewage (Oct.–Dec.)	4.5
Effluents (good)	1.5
Effluents (indifferent)	2.1

Whampoo River water, which had passed through the filtration plant, was used as the dilution water for the B.O.D. tests. Many results were run checking B.O.D.'s obtained with this water *vs.* standard bicarbonate dilution water.

H. HEUKELEKIAN

Refinery Waste Disposal—X. Preventing the Fouling of Cooling Waters Reduces Plant's Waste Disposal Costs. BY W. B. HART. *Petroleum Processing,* **1**, No. 2, 102–8 (October, 1946).

The belief is prevalent that water which is normally out of contact with oil is always uncontaminated, and can be discharged without attention. But usually there are a number of sources of contamination, such as leaks in tubular coolers, spills to sewer inlets, and similar accidents. Precautions can be taken to avoid accidental contamination, and the economy of such measures is obvious, for some wastes can then be disposed without treatment, and the treatment required by others is simple and inexpensive.

Most of the water used in a refinery is cooling water, and tubular equipment causes the major problems of water pollution. Where the cooling water is under greater pressure than the oil, when tube leaks occur the water leaks into the oil and the cooler waste water can be discharged without treatment except, possibly, for temperature correction. But where the pressure conditions are reversed, when leaks occur the cooler water will contain oil and serious pollution may result.

Pollution will not occur in a refinery with a single drainage system and proper treatment facilities because oil leakage will be retained in the plant. Where a separate system is maintained to carry off uncontaminated waste water, pollution can be prevented by installing directional discharges from coolers. Each cooler should be equipped with a sight-box through which the waste cooling water flows to a header connected to the uncontaminated sewer. When an oil leak occurs, the oil will be visible in the sight-box and the water can be diverted to another header connected to the sewer leading to the treatment plant. Such a system will avoid serious pollution because leaks discharging large quantities of oil rarely occur abruptly. Also, this scheme permits construction of a much smaller sewer than would otherwise be necessary.

It is sometimes desirable to hold a reserve supply of water for emergencies. Reserve water tanks could be used to retain contaminated water from a leaking cooler if they were equipped with gooseneck outlets to drain away excess water.

Tars and other products are frequently cooled in a coil of pipe in a box through which a suitably baffled stream of water flows. Oil leakage can be retained by an effluent baffle or by a submerged outlet. A baffled outlet is normally best, because it will serve both where the oil is lighter or heavier than water. Where the oil is consistently heavier than water a submerged outlet should never be used.

Relatively uncontaminated waste water usually need be corrected only for temperature, dissolved oxygen, and toxicity. The degree of correction is a matter for judgment; it will depend on the volume and character of the receiving water. The dissolved oxygen in water is a function of temperature, and water which is too hot for direct discharge can be cooled and reaerated at the same time by allowing it to discharge through a shallow trough equipped with baffles, weirs, cascades, or similar devices. Temperature can be reduced several degrees in 200 to 300 ft. of trough flow, provided the velocity is not excessive. These troughs should be placed where they will receive the effect of wind action.

Where the low flow of a stream is considerably in excess of the waste water discharge, a simple weighted averaging of the two flows will disclose the effect on the stream. It is desirable to calculate the pounds of oxygen required per day by the waste, and then determine the average reduction of oxygen in the stream. If the waste water reduces the oxygen in the stream below about 5 p.p.m. at low flow, additional aeration should be provided.

Toxicity in these waste waters is usually caused by the appearance of metal ions resulting from corrosion. Where the receiving water is hard, these ions will normally be precipitated as the waste mixes with the receiving water. But where the water is soft, or contains insufficient bicarbonate alkalinity to react with all of the soluble metal, serious effects on aquatic life may appear. Standardized fish tests should be used to establish the presence of toxicity. If toxicity is detected, each flow which contributes to the main flow should be tested to locate the source of the trouble; the offending flows can then be diverted to some other treatment for correction.

RICHARD D. HOAK

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Refinery Waste Disposal—XI. Designing Disposal System for Discharge of Uncontaminated Waste Waters. BY W. B. HART. *Petroleum Processing*, 1, No. 3, 193–6 (November, 1946).

The ideal way to solve the problem of industrial waste disposal is not to produce the waste. This is not always possible, but uncontaminated waste water can frequently be reused; this is a fortunate circumstance where water is not plentiful.

Disposal by reuse can be applied in any refinery, and where a single sewer system collects all of the wastes for correction in a final waste treatment plant, reuse of cooling water may remove a major part of the load on the treatment facilities or permit the use of smaller equipment.

Cooling equipment must be protected, however, and the cooling water must not contain oil. It is necessary, therefore, to maintain the same freedom from oil as if the water were to be discharged into clean surface waters.

Where relatively uncontaminated waters, which have been cooled and aerated, must be discharged to surface water there should be provision for rapid admixture with the receiving water. If this is not done, the value of cooling and reaeration will largely be lost. The degree of treatment afforded wastes discharged into streams will depend to a large extent on the base flow of the stream.

In a small, rapid stream, where navigation is not a question, the full width of the stream may be used, unless a fish-way is desirable. Under such conditions, the outfall may extend as far as necessary into the stream, and it should have perforations or other outlets along its submerged length, to provide rapid mixing.

In deeper, more slowly moving streams, a submerged barrier should be placed immediately downstream from the sewer, and a berm of rocks immediately upstream for protection. Such lines usually need not be anchored, but they should be submerged sufficiently deeply to provide protection against floating debris or surface freezing.

For quite deep streams the same kind of construction may be used, but the outfall need extend only part way along the bottom. Such streams may be navigable, and the army engineer or appropriate state agency should be consulted. Large streams are frequently sluggish near the shore, and have one or more main channels which carry the bulk of the flow. In these cases, the sewer should not be perforated, but should extend to a point near a major channel where the greatest turbulence exists. It should terminate in a side-branched cross so that the waste will be discharged horizontally in four directions. The line must be located where its interference with other uses of the stream will be at a minimum.

This type of deep stream construction is chiefly concerned with the protection of aquatic life, which is largely found in the shallower reaches of the stream. Even the largest fish come to these areas to feed and to spawn. It is therefore essential to avoid the discharge of wastes into these sluggish regions.

Proper disposal of wastes into tidal waters presents peculiarly difficult problems. Here the flow is constantly changing; at high tide the point of discharge may resemble a pool stage where efficient mixing is impossible. A survey of the temperatures and currents in the tidal area should

be made by means of floats which can be set to show these conditions at various depths. Such surveys should be made sufficiently often, and at different seasons, to afford all of the necessary data. When this information has been obtained, it is possible to adjust the degree of treatment to the conditions. Construction of holding reservoirs is often helpful, because they will permit advantage to be taken of rapid currents which occur more or less periodically.

Disposal into lakes often involves very difficult problems, involving the laws regulating the use of natural waters for disposal by dilution. It is apparent that the most important factor is the concentration of deleterious factors in the waste, because certain wastes may be lethal if only from osmotic effects; this can even be true in sea water. For this reason, it is essential that the wastes be so dispersed that the concentration of these substances will be reduced below the danger point. Here, again, a satisfactory sewer cannot be laid into a lake until a survey has been made to record temperatures and currents at various levels and during different seasons.

It is important that the inlet end of any disposal sewer be so designed that air bubbles will not be drawn into it. Although the entrainment of air actually is helpful, where the sewer discharges a streak of bubbles, or a grayish film, will often appear which may result in the accusation that the plant is not being especially careful in its waste disposal practice.

RICHARD D. HOAK

Refinery Waste Disposal—XII. Improper Control of Storm Run-off Water May Nullify All Waste Treatment Efforts. BY W. B. HART. *Petroleum Processing*, 1, No. 4, 248–52 (December, 1946).

The handling of storm run-off water has been the subject of probably as much controversy as any other phase of refinery waste treatment and disposal. Surface waters which have been maintained in a clean condition have been so seriously damaged by a single instance of pollution that several years were required for restoration. Such damage often can be traced to storm run-off which flushed away accumulations of waste. There is sufficient evidence to support the claim that all storm water which may become contaminated should be passed through the refinery waste treatment facilities. This gives great importance to means for preventing pollution of surface run-off.

Grade differences, plant layout, kinds of operation, railways, roadways, pipelines, surface structures, and "housekeeping," are the principal items to be considered in protecting run-off against contamination. Grade difference is important because it controls the direction of flow and poses the problem of so restraining the run-off that the greatest quantity is kept free of pollution. Pollution, in this instance, means contact with oil which has escaped accidentally. The places at which these contacts may occur should be determined by a refinery survey, to permit diversion of storm water around them.

Leaks and spills of oil are most likely to occur in areas where equipment is concentrated. It is here that good housekeeping can eliminate sources of potential contamination of storm run-off. Clean-up of spilled oil before it can accumulate and penetrate the subsoil will avoid the necessity for isolating these areas. To be effective, however, the housekeeping must be thorough and continuous. Areas in which there is continual leakage from sampling cocks, pump glands, valves and other devices cannot be included; these locations must be diked and drained to the contaminated sewer system.

Pipelines were formerly regarded as serious sources of pollution, but the current practice of using welded line construction and pressure controls has greatly reduced the hazard from this source. Old lines, however, must still be regarded with suspicion. Loading racks for tank trucks and cars are never free from spills, and these areas must be guarded from storm run-off.

Tank farms may or may not be sewered. Where sewered, a line from inside the dike surrounding each tank should be connected to the contaminated sewer system. Where unsewered, storm water may be drained to the area outside the dikes if any accumulations of oil are first removed or prevented from discharging through the drain. This method of controlling tank farm drainage must be handled carefully; drainage lines

must be kept closed at all times except when in actual use under proper supervision.

Rail and roadways present annoying localized problems where curbs are used to control run-off, especially where they are just at grade. These will require ingenuity on the part of plant personnel, because each instance will comprise an individual problem. As a last resort it is always possible to elevate the roadbed just sufficiently to permit the passage of the curbing underneath.

In controlling storm run-off it is frequently desirable to provide a series of sewers or ditches to reduce, as far as possible, the distance the water flows on the bare ground. This practice will avoid erosion, and will prevent the build-up of water on flat areas during periods of heavy rainfall.

Run-off water from sections which drain to the contaminated sewer system presents a problem important in the design of waste treatment plants. Wherever possible, actual measurements of the rate of run-off should be made because, where these flows must be estimated, the problem is far from simple.

Where run-off rates are to be measured, installations must be made which will remain in place for a sufficient time to experience enough storms to provide the necessary data. A number of factors must be considered as, for example, in flat country the flow differentials will be low, and the drainage measuring devices must be such that they will not back up the flow excessively. The use of fire streams is another element which must be considered in gauging run-off water.

Orifices, weirs, flumes, and velocity meters are used to measure flows, and circumstances will dictate which can best be used in a given instance. Orifices can be used where sewers run full, or at the point of discharge of a sewer where there is sufficient slope to permit the head loss necessary for free discharge from the orifice plate. Weirs can be used effectively in open flumes which can be provided with a stilling chamber to eliminate the effect of velocity of approach. This paper concludes with a description of the methods of installing and using different flow measuring devices.

RICHARD D. HOAK

Experimental Work at the Northern Outfall Works of the London County Council, 1940–1946—Part I. By E. H. VICK. Paper* presented at a meeting of the Metropolitan and Southern Branch of The Institute of Sewage Purification, October 19, 1946. 20 pp.

Most of the experimental work described in this paper was started with a view toward utilizing the organic matter in sludge as a fertilizer due to the expected shortage of inorganic fertilizers during the War. Other experiments were directed to overcoming various technical difficulties experienced in working the plants at the Northern and Southern Outfall Works.

The Northern Outfall Works has the following typical raw sewage analysis expressed in parts per million:

Solids		Chlorions	Nitrogen		5-Day B.O.D.
Suspended	Dissolved		Ammonia	Organic	
386	1040	213	39.9	24.5	300

The average daily dry weather flow is 180 m.g.d. (Imp.). 60 m.g.d. is given activated sludge treatment. Sludge vessels barge 27,000 tons/week to the Thames Estuary.

Dewatering Activated Sludge. Vacuum filter tests were run on a small experimental unit that had a filter cloth area of 3.14 sq. ft. It was fitted with a vacuum pump producing an average vacuum of 20 in. of Hg. and an air compressor giving a blow-back of about 5 lb. per sq. in. The coagulant used in this series of tests was commercial ferric chloride crystals containing 40 per cent by weight of water, the crystals being dissolved in water to make a 45 per cent solution. From the results it appeared that 6 per cent was the optimum amount of coagulant based on dry solids. Chlorinated copperas as a coagulant gave only one half the weight of dry solids as was obtained by $FeCl_3$ when each had a 4 per cent solution.

A series of experiments was carried out on dewatering activated sludge by means of a sludge press of the "Radicon" type which consisted of nine chambers, each 13 sq. in., and capable of producing cake 1

* A preprint.

Vacuum Filter Tests

% $FeCl_3$	Lb. of Wet Cake per Sq. Ft./Hr.	Lb. of Dry Solids per Sq. Ft./Hr.
4.44	3.83	0.605
9.5	4.55	0.66
9.5	5.12	0.72
8.33	4.7	0.686
7.14	3.75	0.543
7.14	3.74	0.591
7.14	4.74	0.673
6.8	2.84	0.435
6.8	3.4	0.538
6.0	4.68	0.722
5.58	4.48	0.628
5.27	3.9	0.582
4.46	2.9	0.40
4.44	3.83	0.605
4.0	3.34	0.45
3.8	4.34	0.556
3.8	4.53	0.57
3.0	2.96	0.323
3.0	3.42	0.442
2.11	2.94	0.365
2.11	3.9	0.475

in., ¾ in. or ½ in. thick. The tests carried out consisted of a comparison of times and cake thicknesses, *i.e.*, 1 in. chambers were tried for 1, 2 and 3 hr. running time and similarly for ¾ in. and ½ in. chambers. From 8.78 per cent to 10.4 per cent of $FeCl_3$ was used as a coagulant. From results it would appear that three runs of one hour duration would give 50 per cent more cake than one run of 3 hr. but in practice it would probably be more efficient to run the press for a period of three hours as, in addition to decreasing the number of times of cleaning the filter cloths, each cleaning would be more simple owing to the relative dryness of the cake. The cake obtained from the press is slightly drier than the cake obtained from the vacuum filter and would consequently require less air drying and hence less bed area. About 15 per cent more of the available solids in the sludge were retained. The amount of labor involved in operating the press and transferring the wet cake to drying beds is approximately the same as for similar operations with a vacuum filter, but in the case of the press additional labor is necessary in dismantling the plates, cleaning the filter cloths and re-assembling the plates.

In view of the impossibility of obtaining a larger vacuum filter during the War, experiments were also carried out on the drainage of activated sludge on sand filters. These experiments were on a larger scale than either the vacuum filter or sludge press experiments. This plant consisted of a cast iron settling tank, two sand filters, an air drying area and a disintegrator. In the first tests ferric chloride was added as a coagulant but as the filter appeared to drain equally well without it, it was discontinued in the later tests. The ability of a sand filter to dewater activated sludge without the addition of a coagulant is an important economic factor. When settled sludge was placed on the beds at 13½ in., 7½ in., and 6½ in., the respective periods before the cake could be lifted were 15, 8 and 11 days. This was reduced to 3 or 4 days when a depth of only 3 or 4 in. was applied. About 50 per cent to 60 per cent moisture was present when the wet cake was lifted from the sand filters and placed on drying beds for a period of one to two weeks. When the moisture content was reduced to between 20 per cent and 30 per cent, the cake was disintegrated and the following analysis is typical:

	Sample as Received	Calculated on Dry Matter
	Per Cent	
Moisture	11.67	—
Residue on Ignition	41.01	46.43
Sand	30.70	34.75
Nitrogen	4.17	4.73
Phosphoric Acid (P_2O_5)	2.02	2.29
Potash (K_2O)	0.37	0.42
Total Carbon	26.6	30.1
Inert Carbon	2.3	2.7
Carbonate Carbon	0.3	0.3
Available Carbon	24.0	27.1

The high percentage of extraneous sand lifted from the filter bed with the cake was the one objection to the sand filter. As well as decreasing the value of the product as a fertilizer the amount of labor involved in ridding the cake was uneconomical. An experiment was therefore put in hand to determine if perforated zinc plates as a cover to the filter media would prevent the adherence of sand. Plates 1/16 in. thick with circular perforations 1/8 in. dia. were

constructed and fitted with lifting frames. In the first trial the sludge cake was removed from the plates after three days and contained only 41.8 per cent moisture. Practically no sand adhered to the cake. In contrast a parallel trial on sand filters alone contained 73 per cent moisture and had a layer of sand on the under surface. In a second trial the moisture contents were 26.1 per cent and 41.9 per cent even though the high figure remained on a direct contact sand filter for eleven days longer. It was concluded that the use of perforated zinc plates appears to enable the sludge to drain more quickly, and it is apparent that the secondary drying period is shortened owing to the thinness of the cake. This enables both filter and drying area to be smaller, or alternatively more frequent use of the filters is possible. The labor in lifting the sludge was very much reduced, and no labor was required to riddle the cake. In addition, as the cake contains very little sand, its value as a fertilizer is improved.

Porous concrete filters constructed from a 12 to 1 mortar were also tried. A typical analysis of the dried cake as lifted from the concrete filters is as follows:

	As Received	On Dry Matter
Moisture	89.42	—
Mineral Matter	2.31	21.83
Acid Insoluble (Sand) and Silicious Matter	0.79	7.46
Nitrogen	0.76	7.23
Phosphoric Acid, P_2O_5	0.38	3.60
Potash, K_2O	0.07	0.63

The results obtained on porous concrete filters might generally be considered to be unsatisfactory compared with those of the sand filter. It was proved that the addition of a small dose of coagulant improved drainage. One problem that remained unsolved was to prevent the solids in the sludge settling out as soon as the sludge was poured on the filter, as those deposited in the first hour form a gelatinous film on the surface of the filter which appears to be almost watertight. However, in view of the fact that concrete filters have many advantages over the sand filter in the operating costs in removing the sludge, the more permanent character of the surface, and the improved quality of the sludge cake due to no extraneous sand being picked up, it was proposed to continue these experiments.

A series of experiments on dewatering activated sludge by a hydro-extractor were carried out. Unfortunately, it was possible to obtain only a laundry type machine. Its perforated sides were lined with filter cloth similar to that used in the vacuum filter. Difficulties were encountered in balancing the machine properly and in removal of the filtered cake; and as it was impossible to obtain suitable equipment, no further experiments were carried out by this method.

Storage of Activated Sludge. During the shutdown of the activated sludge treatment for coal conservation, it was necessary to store activated sludge. Therefore the paddles in one aeration set were operated at the highest speed possible to provide aeration and circulation of the mixed liquor. Once each day the paddles were stopped and the sludge allowed to settle. Out of a total of 1,200,000 gal. (Imp.) usually about 75,000 gal. of supernatant were pumped out, and this was replaced by raw sewage. No diffused air was used. About 140 tons of coal were saved per week. When the plant was restarted on April 1, 1946, the value of this stored activated sludge was apparent, as it enabled the activated sludge tanks to resume operation in a much shorter period than it would have been possible to do otherwise.

Secondary Sedimentation. As a result of the shutting down of the activated sludge plant, the final settling tanks were out of use, and it was decided to use them for secondary sedimentation. Performance proved to be rather variable, as was to be expected, as these tanks were not designed for this purpose. It was noted that at some periods the effluent contained more suspended solids than the influent, in spite of the considerable quantity of sludge removed daily. Generally, the conclusion was reached that the provision of secondary sedimentation tanks would not be an economical proposition, having due regard to the fact that a very high degree of purification is not required.

Sludge Digestion. In 1938 a large scale experimental plant was installed at the Northern Outfall Works designed to treat 44,800 gal. (Imp.) of crude sludge per day.

Sludge Digestion Plant

Analysis of Operation, 1940 to 1946

Year Ending	Crude Sludge				Digested Semi-Sludge					Gas Produced				
												Gas per		
	Amount Treated Tons (Long)	Average Solids %	Av. Loss on Ignition %	Wt. of Dry Organic Matter Lb.	Average Solids %	Average Loss on Ignition %	Wt. of Dry Org. Matter Lb.	Net Wt. of Dry Org. Matter Digester Lb.	Reduction of Dry Org. Matter %	Vol. of Gas Produced Corrected to Nearest 10%	Average Calorific Value B.T.U.	Gal. of Crude Sludge Cu. Ft.	Lb. of Dry Org. Matter in Crude Sludge Cu. Ft.	Lb. of Dry Org. Matter Digested Cu. Ft.
Mar. 30, 1940.....	64,375	6.48	66.84	6,586,890	5.65	54.53	4,462,083	2,134,807	27.57	33,288,985	705	2.41	5.33	15.65
10 months ending Mar. 31, 1942...	50,073	5.33	64.4	3,933,880	4.42	55.22	2,753,485	1,203,841	30.6	24,144,129	709	2.20	6.14	20.06
Mar. 30, 1943.....	54,986	6.10	67.8	5,076,060	4.60	59.30	3,244,608	1,831,452	36.28	28,679,713	709	2.45	5.71	16.14
Mar. 29, 1944.....	64,385	6.00	68.2	5,906,200	4.20	56.50	3,478,390	2,404,820	40.68	32,722,160	701	2.36	5.54	14.54
10 months ending Jan. 29, 1945....	40,100	6.80	67.7	4,197,820	4.90	55.9	2,481,440	1,721,500	40.10	20,364,500	710	2.60	5.39	15.90

The plant consists of 4 digestion tanks, each having a capacity of 100,800 gal. (Imp.). They are covered with a fixed concrete roof fitted with two gas collecting domes to each tank. The sludge was preheated to 110° F. in two heating tanks. Heating is carried out by means of hot water coils in the heating tanks, the water being either condenser cooling water or obtained from gas-fired boilers via calorifiers. The process is one of partial digestion only, as digestion last for 9 days.

As some trouble had been caused by foaming, it was suggested that a reduction of the working temperature in the digestion tanks to 85° F. would be effective. In 1945 the temperature was gradually dropped to 85° F. and the results have been evident in elimination of foaming without reduction in gas production.

A series of experiments was initiated on pre-heating the sludge by direct steam heating. A temporary steam main one in. in diam. was carried down the center of one of the sludge digestion plant settling tanks. The steam was used at a pressure of 160 lb./sq. in., superheated to 550° F. superheat. Results indicated that the steam heating has the advantages of simplicity and low initial cost. The experiments are being continued at the present time and arrangements are being made to measure the steam used directly and to determine the best spacing of the steam jets to give even heating of the whole mass of sludge.

Sludge Thickening. Experiments were made to settle the partially digested sludge after it had been withdrawn from the digester. The presence of entrained gases made this a difficult task. Blowing air through the sludge did not help. It was found that reduction in the temperature to below 75° F. resulted in separation of the liquor, as convection currents probably caused the solids to remain in detention. Another group of experiments showed that effective separation of liquor could be obtained in a stirred tank, and that separation was independent of the temperature.

Mechanical Cleaning of Sedimentation Channels. As sludge is now removed by manual labor, investigations were begun on mechanical methods. A motor-operated scraping mechanism was put in operation in June, 1946, at the Southern Outfall Works, and preliminary experiments indicate that a sludge with a moisture content of 86 per cent to 89 per cent can be obtained. At the Northern Outfall Works, the channels are not well adapted for the installation of mechanical scrapers, so experiments here are directed to determining whether the channels can be desludged by a tractor fitted with a suitable "bulldozing" blade, in place of the manual labor used at present.

ROBERT P. LOWE

Responsibility for Industrial and Municipal Wastes. BY ABEL WOLMAN. *J. Amer. Water Wks. Assn.*, **38**, 883–887 (July, 1946).

Rough estimates indicate that the raw sewage of 47 million persons empties into the receiving bodies of water in this country and that an additional equivalent of 55 to 60 million is added by untreated and uncontrolled industrial wastes. The conditions that prevail throughout many of the important bodies of water have been studied and restudied, surveyed and resurveyed almost *ad nauseam,* and the results have all served very important and useful purposes. They have tended to increase the body of technical knowledge regarding the conditions that prevail. However, they all indicate one thing—that, by and large, although progress is substantial, it is slow. It is slow on the public side, and it is slower on the industrial side. All of these evaluations indicate that we are confronted with a substantial bill of between two and three billion dollars for necessary major corrections in present conditions.

Public interest can be divided into at least the three following groups—(1) the right wing or gradualist group that feels that progress has been fairly good and that the general result is not too bad, (2) the extreme left, exemplified by the Wild Life Federation and the Izaak Walton League, who feel that progress is infinitesimal, and (3) the large group in between who feel that accomplishment is desirable and that much can be and should be done to speed up processes and undertakings. From action already taken the states appear to be aware of the above extremes in viewpoint.

During the past seven or eight years there has been an increasing tendency to

secure federal government legislation on stream pollution. Testimony has indicated that there needed to be a new stimulus by the federal government, new interest in the general topic and new administrative development. The proposed compromise bill (HR 6024), recommended for passage by the Rivers and Harbors Committee, almost completely eliminates state participation in most of the administrative and regulatory features. This federal participation is at least proposed on a higher level than is generally considered to be the desire of a great many people interested in this particular field. The author believes that this situation has resulted from the difficulties caused by the right of industry to discharge into a body of water such things as it has not found desirable or profitable to remove from its industrial wastes. In turn, it has driven a great many people in this country, including a great many members of Congress, to move in the direction of increased federal responsibility. This definite turn toward federal participation can only be stemmed by increased assumption of local responsibility by the local authority.

Industry can avoid future repetition of the existing conditions by considering the cost of treatment of wastes to be a fundamental part of the cost of production. New plants should be designed in such a way that we would no longer find, as we do in most plants, sewers frequently under or around buildings, and so mixed up that it is impossible to separate the waste from the cooling water. The inclusion of research activities on industrial wastes with other research products of the industry in contrast to focusing it all on products for sale should be definite procedure. A final principle should emphasize that a technological conscience needs to be substituted for legal advice. The author would like to see industry, and the municipality as well, move out of the lawyer's office into the research laboratory.

ROBERT P. LOWE

Stream Pollution Control in Indiana. BY RALPH B. WILEY. *J. Amer. Water Wks., Assn.*, **38**, 1041–1045 (September 1946).

In 1935 stream pollution control in Indiana was made a function of the Department of Commerce and Industry, but this Department was abolished in 1941. In 1943 a new law provided for the establishment of a Stream Pollution Control Board. The Board now consists of three *ex-officio* members, the Lieutenant Governor, the Director of the Department of Conservation and the Secretary of the State Board of Health. In addition, the present board includes a representative from industry, a Farm Bureau member to represent agriculture and two engineers. Under the provisions of the law, all engineering assistance is furnished by the State Board of Health; and the Secretary of the State Board of Health has appointed the Chief Engineer of the State Board of Health to act as Secretary to the Stream Pollution Control Board.

By 1940 complete treatment was installed for 62 per cent of the urban population in Indiana and a total of 70 per cent of the urban population was receiving treatment of some kind. In the past two years the Stream Pollution Control Board has issued orders against 35 cities and towns. When all of these plants are completed, the sewage of 86 per cent of the urban population will be receiving satisfactory treatment and that of 94 per cent will be receiving treatment of some sort. Prior to 1940, seven industrial plants and 24 governmental institutions had treatment plants; orders have now been issued against 7 industries and 1 school. Several state institutions have voluntarily begun work on plants.

The law specifically provides that the board "shall have jurisdiction to control and prevent pollution in the waters of this state with any substance which is deleterious to the public health or to the prosecution of any industry or lawful occupation, or whereby any fish life or any beneficial animal or vegetable life may be destroyed, or the growth or propagation thereof prevented or injuriously affected." As the board is required "to determine what qualities and properties of water shall indicate a polluted condition," a resolution was adopted that in general made the following standards applicable to all receiving waters:

(1) Elimination of discharge of floating material existing in deleterious amounts or in amounts sufficient to injuriously affect fish life, fur bearing or domestic animals,

or the general biology of the water, or plant life in, or in the vicinity of such water.

(2) Exclusion of wastes that form putrescent or otherwise objectionable sludge banks.

(3) Exclusion of materials in concentrations sufficiently high to affect adversely public health, fish life, fur bearing or domestic animals, or plant life in, or in the vicinity of such water.

(4) Standardization of 50 per cent oxygen saturation as the depletion limit after the waste is mixed in the receiving water (25 per cent saturation will be tolerated temporarily).

(5) A maximum coliform concentration of 1,000 per 100 ml. (M.P.N.) for bathing and 5,000 per ml. (M.P.N.) in the vicinity of a water supply intake.

(6) Removal of tastes and odors from wastes discharged in sources of water supply.

The law provides that a city or industry can appeal to the circuit or superior court from an order of the board and either party can demand a jury trial. As determination of the existence of a polluted condition is final only after determination by the court, the board must first be prepared to prove that its order is reasonable, and second, that all provisions of the law have been complied with. The board feels certain that the adopted standards are reasonable, but only a court decision can settle the matter. However, the board has been advised that it seems most reasonable to clean up streams where there is positive evidence of pollution, rather than risk losing a case in court if the board should proceed in an arbitrary way.

A state act provides that funds to comply with orders of the Stream Pollution Control Board may be obtained by the issuance of either direct obligation bonds or revenue bonds, but they shall constitute a sanitary fund, and shall be used for no other purpose. Steps have been taken to see that the entire procedure has the approval of a firm of bond attorneys, as it would be embarrassing to the board to have such bonds declared illegal because some step in the necessary action was omitted or improperly taken.

ROBERT P. LOWE

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Book Review

Manual for Sewage Plant Operators. By L. C. Billings, *Editor-in-Chief*. Published by the Texas Water Works and Sewerage Short School, V. M. Ehlers, Secretary, 410 East Fifth St., Austin 2, Texas. 435 pages. Price $3.50.

This book could not be more exactly titled. Developed as a text for the instruction of sewage works operators (Texas operators are required to be certified under a state law enacted in 1945), it is a "grass-roots" presentation of the information on sewage works theory, practice and administration that is admirably suited to its purpose.

The manual is a product of the Texas Sewage Works Section of the Texas Water Works and Sewerage Short School, a Member Association of the FSWA. A special committee consisting of W. S. Mahlie, Chairman, Irving M. Dietz, Jr., and I. A. Ronhovde administered the project. A total of 29 authors collaborated in writing the 27 chapters, as follows (chapter titles rephrased for brevity):

Chapter No.	Subject	Authors
I	Nature of sewage	W. S. Mahlie
II	Public health aspects	Dr. Geo. M. Cox
III	Sewer design	H. R. F. Helland
IV	Pumping stations	H. M. Bohn
V	Sewer maintenance	R. U. Andrews A. B. Carson, Jr.
VI	Organization and finance	E. E. McAdams
VII	Sewage irrigation	J. P. Burden
VIII	Screens, grit chambers, etc.	J. D. Fowler
IX	Septic tanks	L. J. Trotti
X	Imhoff tanks	Lewis Dodson
XI	Primary sedimentation	Terrell Bartlett
XII	Chemical precipitation	E. J. Umbenhauer Haskell R. Street
XIII	Sand filters	S. M. Field
XIV	Trickling filters	R. M. Dixon
XV	Activated sludge	E. J. M. Berg
XVI	Separate sludge digestion	E. J. M. Berg
XVII	Sludge drying beds	S. L. Allison
XVIII	Mechanical sludge dewatering	G. L. Fugate
XIX	Chlorination	I. M. Dietz, Jr.
XX	Other treatment processes	Ashley G. Classen
XXI	Plant maintenance	L. C. Billings
XXII	Industrial wastes	C. H. Billings
XXIII	By-products of sewage treatment	Clyde C. Hays
XXIV	Stream pollution	W. P. Walker, Jr. A. C. Kellersberger
XXV	Laboratory control	J. H. Sorrells
XXVI	Sewage works mathematics	P. J. A. Zeller
XXVII	State requirements	V. M. Ehlers

Collation and editing of the book has been creditably handled by L. C. Billings, Editor-in-Chief, and Associate Editors W. S. Mahlie and Margaret M. Roddy.

Primary emphasis is given to operation procedures for all parts of the sewer system and sewage treatment plant, with enough of the theory and design background concerning each process to afford a good practical coverage. All fundamental calculations are indicated and explained, and illustrative examples are given in many cases. Charts, graphs and line drawings are used to good advantage to supplement the text. Lists of review questions are provided at the end of each discussion to assist the reader in preparing for certification examinations.

This manual will be of greatest usefulness to plant operators who have had limited technical education, and to "transplanted" engineers and chemists who have entered the sewage works field from other lines of endeavor. It is the best textbook for short course instruction that has as yet come to the attention of this reviewer. Only 1,500 copies of the book have been printed, a supply which will undoubtedly be inadequate to meet the ultimate demand.

W. H. WISELY

Special Notice

To All Present And Former Sanitary Corps Officers

Please communicate with Colonel M. J. Blew, giving rank; when called to active duty; present rank or rank on separation; specialty (engineering, entomology, parasitology, bacteriology, chemistry, nutrition, etc.); a resumé of pertinent facts regarding active duty assignments; academic and professional degrees; professional and honorary society affiliations; whether registered or certified, etc.

This information is desired to complete an accurate postwar roster and also in preparing an analysis and evaluation of the activities and contributions of the Corps during the war. Existing information is inaccurate and incomplete and the cooperation of all officers and former officers is desired so that a correct picture of their accomplishments can be prepared.

Send data to:

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